THE BENEFITS AND CHALLENGES OF PRODUCING LIQUID FUEL FROM COAL: THE ROLE FOR FEDERAL RESEARCH

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED TENTH CONGRESS

FIRST SESSION

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THE BENEFITS AND CHALLENGES OF PRODUCING LIQUID FUEL FROM COAL: THE ROLE FOR FEDERAL RESEARCH

WEDNESDAY, SEPTEMBER 5, 2007

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENERGY AND ENVIRONMENT,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The Subcommittee met, pursuant to call, at 10:05 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Nick Lampson [Chairman of the Subcommittee] presiding.

BART GORDON, TENNESSEE
CHAIRMAN

RALPH M. HALL, TEXAS
RANKING MEMBER

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THE SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

HEARING ON

THE BENEFITS AND CHALLENGES OF PRODUCING LIQUID FUEL FROM COAL: THE ROLE FOR FEDERAL RESEARCH

Wednesday, September 5, 2007
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

WITNESSES:

Dr. Robert L. Freerks
Director of Product Development, Rentech Corporation

Mr. John Ward
Vice President, Marketing and Governmental Affairs, Headwaters, Incorporated

Dr. James T. Bartis
Senior Policy Researcher, RAND Corporation

Mr. David G. Hawkins
Director, Climate Center, Natural Resources Defense Council

Dr. Richard D. Boardman
The Secure Energy Initiative Head, Idaho National Laboratory

Dr. Joseph Romm
Former Acting Assistant Secretary, Office of Energy Efficiency and Renewable Energy, Department of Energy; Senior Fellow, Center for American Progress

HEARING CHARTER

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

The Benefits and Challenges of Producing Liquid Fuel From Coal: The Role for Federal Research

WEDNESDAY, SEPTEMBER 5, 2007
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On Wednesday, September 5, 2007 the Subcommittee on Energy and Environment of the Committee on Science and Technology will hold a hearing to receive testimony on the use of coal to produce liquid fuel, the status of coal-to-liquid (CTL) technologies and what additional research, development and demonstration programs should be undertaken at the Department of Energy or other agencies to better understand the benefits and barriers to converting coal into transportation fuels.

The Subcommittee will hear testimony from six witnesses who will speak to a range of policies that warrant consideration before moving forward with the advancement of the production of synthetic transportation fuels from coal. Policies for consideration include carbon dioxide management, infrastructure improvements, water usage, energy security, energy balance of CTL technologies (energy used and produced), exhaust emissions, options for using coal with organically derived feedstocks to produce liquid fuels, coal production requirements, potential outcomes for consumers, and the appropriate level of federal investment in CTL technologies. They also will discuss the technical and economical challenges with meeting any desired policy objectives as well as the benefits and drawbacks of investing federal resources in CTL technologies.

Witnesses

Dr. Robert L. Freerks, Director of Product Development Rentech Corp., Denver, CO. He will speak to the state of development of CTL technologies using the Fischer-Tropsch process. He will highlight the benefits of the commercialization of the F–T process and discuss some of the challenges.

Mr. John Ward, VP, Marketing and Governmental Affairs Headwaters, Inc., South Jordan, Utah. He will discuss the growing global demand for oil and the need to explore alternative liquid fuel options using the Nation's abundant coal reserves. He will review the local and global economic benefits as well as the national security and environmental benefits.

Dr. James Bartis, Sr., Policy Researcher, RAND Corp., Arlington, VA. He will address economic and national security benefits of CTL technology as well as the technical challenges for addressing the carbon dioxide emissions resulting from the CTL process. He will also provide suggestions for federal activities needed to address the uncertainties surrounding CTL technology.

Mr. David G. Hawkins, Director, Climate Center at Natural Resources Defense Council, Washington, DC. He will speak to the environmental concerns associated with the adoption of CTL technologies—in particular, the "well-to-wheel" emissions of these new fuels and the impact on global climate change. He will also address other energy strategies which still rely on coal, but help to reduce our nation's carbon dioxide footprint at the same time.

Dr. Richard D. Boardman, The Secure Energy Initiative Head, Idaho National Laboratory, Idaho Falls, ID. He will discuss water resource management related to the production of liquid fuels from coal. He will also address the potential for producing liquid transportation fuels using coal with organically derived feedstocks.

Dr. Joseph Romm, Center for Energy & Climate Solutions; Center for American Progress; former Acting Asst. Secretary at Department of Energy during the Clinton Administration, Washington, DC. He will address the environmental policy considerations related to advancing CTL technology. He will focus on the role of CTL technology in a world with greenhouse gas constraints.

Background

The coal-to-liquids (CTL) process was discovered by German scientists and used to make fuels during World War II. Since that time, there has been varying intensity of interest in this technology. As the price of petroleum and natural gas stays high, there will be an increasing interest in developing the commercial potential of producing synthetic liquid fuels from coal.

There are a number of proposed CTL projects in the United States and overseas, and SASOL in South Africa has a long history with CTL. According to the 2007 Massachusetts Institute of Technology (MIT) Report *"The Future of Coal,"* SASOL has been producing 195,000 barrels per day of liquid fuel using Fischer-Tropsch technology for several decades. In addition, jet fuel from a gas-to-liquids pilot plant has already been certified for use by the United States Air Force.

There are two mainstream processes for producing liquid fuels for transportation applications: direct and indirect. It is generally the indirect route for liquid fuel production that is discussed in the United States. A good explanation for the focus on the indirect process is the fact that SASOL in South Africa has commercialized that technology increasing the confidence in the indirect approach to liquefaction. In addition, the MIT Report explains that converting coal *directly* to liquid products requires reactions at high temperatures and high hydrogen pressure. This liquefaction route is very costly due to the type of equipment needed to operate at these conditions. The MIT report also states that in general, the direct liquefaction route "produces low-quality liquid products that are expensive to upgrade and do not easily fit current product quality constraints."

Indirect Liquefaction Process

As described by the MIT Report the initial step in the production of methane, chemicals, or liquids from coal is the gasification of coal to produce a syngas—this is the same process carried out in Integrated Gasification Combined Cycle (IGCC) for electricity generation. The synthesis gas, or syngas, (predominantly carbon monoxide and hydrogen) is cleaned of impurities and a water gas shift reaction increases the hydrogen to carbon monoxide ratio. Then, a Fischer-Tropsch reaction converts a mixture of hydrogen and carbon monoxide to liquid fuels. The hydrogen and carbon monoxide can be derived from coal, methane or biomass.

Challenges With CTL

The MIT report states that "Without CCS (carbon dioxide capture and storage), Fischer-Tropsch synthesis of liquid fuels emits about 150 percent more CO_2 as compared with the use of crude oil derived products." Requiring these facilities to capture and sequester the carbon dioxide will make the synfuels more expensive. However, the MIT report also points out that carbon capture and storage would not require major changes to the synfuels process or significant energy penalties because the CO_2 is byproduct in an almost pure stream and easier to capture and manage.

In addition, questions have been raised about the ability to guarantee a dependable and sustained market for coal-to-liquid fuels which could deter private-sector investment. Specifically, industry has expressed concern that the uncertainty of world oil prices coupled with the technical risks associated with the operation of the initial commercial plants and the implementation of carbon dioxide management options will make private investment difficult to obtain.

CTL plant costs will vary based on location, capacity, construction climate, product slate and coal type. The Fishcer-Tropsch synthesis using coal has been criticized as inefficient and thus costly. The MIT report concludes, "Today, the U.S. consumes about 13 million barrels per day of liquid transportation fuels. To replace 10 percent of this fuels consumption with liquids from coal would require over $70 billion in capital investment and about 250 million tons of coal per year. This would effectively require a 25 percent increase in our current coal production which would come with its own set of challenges."

Benefits From CTL

Production of domestic liquid fuel would help secure energy supplies by displacing imports of diesel or jet fuel. Refiners cannot meet U.S. demand for these fuels so diesel or jet fuel production from CTL facilities would offset imports.

"Unlike conventional transportation fuels, CTL fuels, made using an indirect liquefaction process, produce tailpipe emissions that are almost completely free of sulfur." (*Coal International*—January/February 2007)

"Carbon dioxide emissions, over the full fuel cycle, can be reduced by as much as 20 person, compared to conventional oil products, through the use of carbon capture and storage." (Williams & Larson 2003, Princeton University, "A comparison of direct and indirect liquefaction technologies for making fluid fuels from coal," *Energy for Sustainable Development,* Volume VII, No. 4, December 2003).

Table 1. Comparative Merits and Drawbacks of Fishcer-Tropsch (CRS RL34133)

Abundant coal reserves available as feedstock.	↔	Competition for coal in electric Power generation.
Coal-to-liquids generates significant CO_2	↔	CO_2 separation during synthesis gas production makes capture feasible.
Produces ultra-low sulfur, high cetane diesel.	↔	Produces low-octane gasoline
Low efficiency in converting coal to liquid.	↔	waste heat available for electricity co-generation.
May have lower operating expenses than direct coal liquefaction	↔	Conceptually more complex than direct liquefaction approach and higher in capital investment cost.
Deep geologic sequestration offers solution for CO_2 emissions.	↔	CO_2 sequestration not yet demonstrated on a large industrial scale.
Gas-to-liquids offers reduced CO_2 generation.	↔	Competition with domestic natural gas use.
Biomass-to-liquids offers zero carbon footprint.	↔	Competition with biomass for cellulosic ethanol production.

Chairman LAMPSON. Good morning. This meeting will come to order. I am pleased to welcome our panel of witnesses here this morning. As you may recall during the—during our Committee markup at the end of June Chairman Gordon committed to holding a hearing on the topic of liquid fuel production from coal. And I am pleased that we are able to host such an expert panel of witnesses today to discuss the barriers and benefits of using our abundant coal resources to produce liquid transportation fuels.

I understand that many supporting the coal-to-liquid technology do so at least in part because this technology could help to decrease oil imports. There is no question that we must reduce our reliance on foreign oil supplies, and I have worked to ensure the Federal Government continues to play a role, a critical role in the development of bio-based fuels as an alternative to petroleum for transportation fuel.

Achieving greater energy independence will take collaborative work from a range of experts. We need to fully explore all of our options for diversifying our fuel use. I sincerely hope that the urgency to achieve greater fuel supply diversity, energy independence, and fuel use efficiency will not lead us to turn a blind eye toward the pressing issue of global climate change. We have a need to have a comprehensive strategy to build an energy future that is sustainable.

And I recognize there may be economic and strategic benefits of advancing coal-to-liquid technologies from both the regional and the global perspectives. I am also interested in learning more about the possibility of combining coal with biomass to produce liquid transportation fuels.

I further understand that converting coal into transportation fuels helps reduce the emissions coming from our tailpipes.

However, I am also aware that there are significant environmental challenges associates with using coal to produce liquid fuels. I believe it is essential that we continue to examine our energy strategies with attention to the issue of global warming and other environmental concerns such as management of our water resources.

I am also interested in the price implications of creating a second market for coal that will compete with coal's use in electricity and the electivity generation and in the projected lifespan of our coal reserves.

We can't build a coal-to-liquid industry overnight, nor should we fully embrace coal-to-liquid technology as part of our energy strategy until we have thoroughly examined all of the relevant concerns and plotted our next steps sensibly and in a manner that puts our federal resources to good use.

Again, I would like to welcome our witnesses and say that I look forward to your testimony and your recommendations for the Committee.

At this time I would yield to my distinguished colleague from South Carolina, our Ranking Member, Mr. Inglis, for an opening statement.

[The prepared statement of Chairman Lampson follows:]

PREPARED STATEMENT OF CHAIRMAN NICK LAMPSON

I am pleased to welcome our panel of witnesses here this morning. As you may recall, during our Committee markup at the end of June, Chairman Gordon committed to hold a hearing on the topic of liquid fuel production from coal.

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We cannot build a coal-to-liquid industry overnight and nor should we fully embrace CTL technology as part of our energy strategy until we have thoroughly examined all of the relevant concerns and plotted our next steps sensibly and in a manner that puts our federal resources to good use.

Again, I would like to welcome our witnesses and say I look forward to your testimony and your recommendations for this committee.

At this time, I would like to yield to my distinguished colleague from South Carolina, and our Ranking Member, Mr. Inglis for an opening statement.

Mr. INGLIS. Thank you, Mr. Chairman. I appreciate the opportunity to participate in this hearing.

And this afternoon Coca-Cola and the United Resource Recovery Corporation will be announcing their intent to build in Spartanburg, South Carolina the largest bottle-to-bottle recycling plant in the world. The plant will recycle 100 million pounds of plastic for reuse each year, enough plastic to make two billion, 20-ounce Coca-Cola bottles. That is a lot of Coke.

The plant will bring jobs to the South Carolina's fourth district, require less energy than producing bottles from unused materials, reduce waste, and lessen carbon dioxide emissions by one million metric tons over the next ten years.

It wasn't long ago when the best way we knew to deal with waste from bottles was to dig a hole and bury it. When we found out that strategy wasn't the best use of resources, nor environmentally sound, we innovated and started recycling.

I suppose that when we first started realizing the negative effects of burying our plastic, someone could have and may have suggested that we just bury the waste in a different place, maybe at the bottom of the ocean. In retrospect, it is easy to see that that approach, while newer looking, was equally problematic.

So, plastics are everywhere, and we learned how to innovate. In the same way coal is a fact of life in our current energy situation,

and we have an opportunity to innovate to make it the most efficient, to make the most efficient use of that resource.

And coal is a lot like those plastics. At one point we thought burning it in kettle stoves was a good way to heat a home. Now, the challenges of carbon emissions and greenhouse gases cause us to rethink that strategy.

I am concerned that we may be headed down the wrong track here in gasifying coal for transportation use. It makes a lot of sense to use coal, for example, in Integrated Gasification Combined Cycle technology that is stationary, and it makes it so we can produce electricity, and then use that electricity in things like plug-in hybrids. And we can also generate hydrogen power out of similar use of that technology by capturing the hydrogen.

But I have significant concerns about whether this is the right path, to make it into a liquid and make it a portable transportation fuel. It seems to me that there are other portable transportation fuels. We can't put a reactor in our trunk, and we can't clamp a windmill on the back bumper. So we need to find some portable energy source for our cars, and perhaps I could be convinced that coal-to-liquid is a good idea for transportation purposes, but I come with great skepticism about whether it would work or whether it is desirable.

So I look forward to hearing the testimony, and Mr. Chairman, I yield back.

[The prepared statement of Mr. Inglis follows:]

PREPARED STATEMENT OF REPRESENTATIVE BOB INGLIS

This afternoon, Coca-Cola and the United Resource Recovery Corporation will be announcing their intent to build, in Spartanburg, South Carolina, the largest bottle-to-bottle recycling plant in the world. The plant will recycle 100 million pounds of plastic for reuse each year—enough plastic to make two billion 20-ounce Coca-Cola bottles. The plant will bring jobs to the district, require less energy than producing bottles from unused materials, reduce waste, and lessen carbon dioxide emissions by one million metric tons over the next 10 years.

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I suppose that when we first started realizing the negative effects of burying our plastic, someone could have, and may have, suggested that we just bury the waste in a different place—maybe at the bottom of the ocean. In retrospect, it's easy to see that that approach, while newer looking, was equally problematic.

So, plastics are everywhere, and we learned how to innovate around that reality. In the same way, coal is a fact of life in our current energy situation, and we have an opportunity to innovate the most efficient uses of that resource.

Coal's a lot like those plastics. At one point, we thought burning it in kettle-stoves was a good way to heat a home. Now, the challenges of carbon emissions and greenhouse gases cause us to re-think that strategy.

I'm concerned that we may be headed down the wrong track here in gasifying coal for transportation use. Instead of finding a different way to burn coal out of a different pipe (car exhaust instead of a factory smokestack), there's an opportunity to chart a new path. By encouraging Integrated Gasification Combined Cycle (IGCC) technology, we can reduce our dependence on foreign oil by utilizing our coal resource. We can address climate concerns by capturing and sequestering nearly all of the carbon emissions. Finally, from that coal, we can produce clean energy—electricity and hydrogen that can fuel plug-in and hydrogen-powered vehicles.

Before we knew any better, we could talk energy without talking about climate. We no longer have that luxury. I hope that the coal developments we encourage take both into account, and support the American innovative spirit in creating a new energy economy.

Thank you, Mr. Chairman. I yield back.

Chairman LAMPSON. Thank you, Mr. Inglis.

If there are Members who wish to submit additional opening statements, your statements will be added to the record at this point.

Oh, Mr. Hall from Texas, we would recognize you for five minutes. The Ranking Member on the Full Committee.

Mr. HALL. I am sorry, Mr. Chairman, to be late, but I did want to give an opening statement, and I was trying to read it one time before I gave it.

Chairman LAMPSON. Did you make it?

Mr. HALL. Not quite.

Chairman LAMPSON. All right.

Mr. HALL. I would like to thank you for having this very, very important hearing today. You and I are both from energy states, and we have similar ideas about it. I hope we can get together.

I have stated a lot of times that coal is an important part of our domestic energy mix, and it should be and certainly it should be continued to be so through broadened use and particularly coal-to-liquids.

One of our witnesses, Dr. Bartis, states in his testimony that, "OPEC revenues from oil exports are about $700 billion a year." $700 billion. Now, we are handing countries like Venezuela, Iran, Libya, Saudi Arabia hundreds of billions of dollars a year. Why? Well, because unfortunately, there are those in this country that feel it is better to give $700 billion to unstable foreign governments than it is to invest in our own country, our own workforce, our own national security, and our own national independence.

And so today we are talking about coal-to-liquids technology, of which I have been supportive in this and previous Congresses. Just this year alone, we have attempted several times to include common-sense language to bills that have passed through this committee and onto the House Floor, language that is, in fact, supported by some of our witnesses' testimony, but all of which was ultimately defeated.

I know that we have to worry not only about energy supply but also about the effects of energy exploration, production, and consumption on our own environment. And I have faith in our scientists and inventors that they will devise ways to increasingly reduce emissions from the energy life cycle of fossil fuels. We have to have fossil fuels. It is ridiculous to think we are going to do without them or we are about to do without them.

If we can invent ways of—for humans to live in space, we can continue to improve the capture and sequestration of carbon dioxide and other greenhouse gases. I have said it before; we should use all domestic resources to arrive at energy independence. We need renewable energy and plug-in hybrids, but we also need clean coal technology, nuclear power, and environmentally-responsible exploration and drilling for oil and natural gas on American soil and in American waters.

While we continue R&D into renewable fuels and alternative vehicles, we still need fossil fuels in order to maintain the lifestyle that we Americans deserve and that makes the United States of America the greatest country in the world. The alternative is send-

ing our young overseas to take some energy away from people when we don't have to. We have plenty right here at home.

Thank you. I yield back my time to a good Chairman.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF REPRESENTATIVE RALPH M. HALL

Thank you Chairman Lampson. I would like to thank you for having this very important hearing today. I have stated many times that coal is an important part of our domestic energy mix and that it should continue to be so through broadened use—in particular, coal-to-liquids.

One of our witnesses, Dr. Bartis, states in his testimony that, "OPEC revenues from oil exports are about $700 billion a year." $700 billion a year. We are handing countries like Venezuela, Iran, Libya, and Saudi Arabia hundreds of *billions* of dollars a year. Why? Because unfortunately, there are those in this country that feel it is better to give $700 billion dollars to unstable foreign governments than it is to invest in our own country, our own work force, our national security and our energy independence.

So today we're talking about coal-to-liquids technology, of which I have been supportive in this and previous Congresses. Just this year alone, Republicans have attempted, several times, to include common sense language to bills that have passed through this committee and on the House Floor. Language that is in fact supported by some of our witnesses's testimony, but all of which was ultimately defeated by the Majority. I know that we have to worry not only about our energy supply, but also the effects of energy exploration, production and consumption on our environment. I have faith in our scientists and inventors that they will devise ways to increasingly reduce emissions from the energy life cycle of fossil fuels. If we can invent ways for humans to live in space, we can continue to improve the capture and sequestration of carbon dioxide and other greenhouse gases.

I've said it before—we need it all. We need renewable energy and plug-in hybrids, but we also need clean coal technology, nuclear power and environmentally responsible exploration and drilling for oil and natural gas on American soil and in American waters. While we continue R&D into renewable fuels and alternative vehicles, we still need fossil fuels in order to maintain the lifestyle that we Americans deserve and that makes the United States of America the greatest country in the world.

Chairman LAMPSON. Thank you, Mr. Hall. You did a good job.

Mr. HALL. Would you like me to read it again?

Chairman LAMPSON. Well, the second time could get better.

Mr. HALL. I do really thank you.

Chairman LAMPSON. You are welcome. We thank you.

Now I can say that if there are other Members who want to enter something into the record, you may do so, and we will, it will be done at this point in the record.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good morning. Mr. Chairman, thank you for calling this important hearing to examine the benefits and challenges of producing liquid fuel from coal and to identify necessary research to overcome the challenges of converting coal to liquids.

In the past several months, Congress has focused on energy reform and ways to address our dependence on foreign oil while maintaining a sound environment and national economy. Given the volatility of the oil and gas markets, it makes sense to develop policies that place a greater dependence on domestic resources, and coal-to-liquids is one way to help achieve this goal.

In 2006, the United States ranked as the top world-wide consumer of oil, consuming 20.6 million barrels of oil per day and importing 12.2 million barrels per day. China was next, consuming 7.3 million barrels per day and importing 3.4 million barrels per day. While China still trails the United States in consumption and importation levels, it is dedicating substantial amounts of funds to coal-to-liquids and other technology in an effort to become more energy independent.

The United States has an abundant supply of coal, and I firmly believe coal-to-liquids, particularly in combination with carbon capture and storage (CCS) and

other technologies, is part of the solution to achieving U.S. energy independence, continued economic prosperity and improved environmental stewardship.

Fuels produced by coal-to-liquids are cleaner than petroleum-derived transportation fuels. Coal-to-liquids plants using CCS can produce fuels with life cycle greenhouse gas emission profiles that are as good as or better than that of petroleum-derived products.

In February, I joined Chairman Gordon and twenty-five other House Democrats in sending a letter to Speaker Pelosi and Majority Leader Hoyer stating our strong commitment to advancing the deployment of clean coal technologies, including CCS. In order for CCS technology to become commercially viable, the Federal Government must show it is committed to funding the necessary research, development, and demonstration (RD&D) projects.

Mr. Chairman, as you know, I have been a strong advocate for federal coal initiatives and programs. I intend to continue to work with my colleagues on both sides of the aisle to ensure we continue to advance clean coal technology to overcome the technical and economical challenges for coal-based power plants.

To that end, I am glad we are having today's hearing because it is imperative that we understand the benefits and the challenges that must be addressed for coal-to-liquids. I look forward to hearing from the witnesses on these issues, and specifically their recommendations on necessary research and development projects that would further clarify the benefits and challenges in the deployment of coal-to-liquids fuels.

[The prepared statement of Mr. Wilson follows:]

PREPARED STATEMENT OF REPRESENTATIVE CHARLES A. WILSON

Thank you, Mr. Chairman, for holding this important hearing. I appreciate having the opportunity to participate this morning.

I would like to welcome today's witnesses; I look forward to hearing their views on coal-to-liquid (CTL) fuel technology. This hearing offers us a great opportunity to discuss the positive implications of the development of CTL fuel technologies, and the role Congress can play in helping this energy resource become a viable option in the United States.

With energy prices continuing to rise, it is vital that we work to find new technologies to aide in reducing our nation's dependence on foreign energy sources. Coal is our nation's most abundant resource and must play a role in building our energy future.

CTL fuel conversion is a proven technology that is currently in use throughout the world. Coal-to-liquid technologies have been used since World War II, and today, South Africa uses the technology to produce approximately 40 percent of its transportation fuels.

In fact, in my district, Baard Energy, L.L.C., is in the development phase of building a 35,000 barrel per day coal-to-liquids facility in Wellsville, Ohio. The facility's unique design and operation has the potential to sequester up to 85 percent of all carbon dioxide produced, and will be capable of producing synthetic jet fuel, diesel fuel and other valued chemical feedstocks. Additionally, the Wellsville facility is estimated to have a major impact on the regional economy, creating up to 200 high-paying plant jobs and 750 new mine jobs.

While I understand that there are some obstacles to coal-to-liquid fuels, I believe that they can be overcome with the help of the Federal Government. That being said, I am excited to bring CTL research and technologies to the forefront of Congress's discussion on energy independence and security. Again, thank you all for coming today—I am looking forward to hearing from you all today and working together in the future.

[The prepared statement of Mr. Bartlett follows:]

PREPARED STATEMENT OF REPRESENTATIVE ROSCOE G. BARTLETT

There are a number of important national security and environmental considerations involved with coal-to-liquids technologies, including global peak oil, a topic I have discussed many times. This committee and the Full House have previously addressed the topic of coal-to-liquid (CTL) technologies on a number of occasions. I appreciate the opportunity to gather a summary of important actions to date into the record for this hearing.

In an effort to begin moving forward with research and development into using coal-to-liquids for energy Republicans in April of this year offered a Motion To Recommit to H.R. 363, the *Sowing the Seeds Through Science and Engineering Re-*

search Act. This language authorized the Director of the Office of Science at the Department of Energy when carrying out a program to award grants to scientists and engineers at the early stage of their careers at institutions of higher education and research organizations to prioritize grants expanding domestic energy production and use through coal-to-liquids and advanced nuclear reprocessing. These grants were for up to five years and at least $80,000 per year. This language was accepted and approved on the House Floor by a vote of 264 to 154. H.R. 363 including this language went on to pass the House Floor that day by a vote of 397–20. Furthermore, H.R. 2272, the *21st Century Competitiveness Act of 2007,* which combined several Science and Technology competitiveness bills, including H.R. 363, passed the House Floor under suspension of the rules and by voice vote.

At the appointment of conferees on H.R. 2272, the *21st Century Competitiveness Act of 2007,* Ranking Member Hall offered a motion to instruct conferees asking that the managers on the part of the House at the conference on the bill be instructed to insist on the language prioritizing the early career grants to science and engineering researchers for the expansion of domestic energy production and use through coal-to-liquids technology and advanced nuclear reprocessing. This non-binding motion passed the House Floor by a vote of 258 to 167.

Just two days later when the conference report on H.R. 2272 came to the Floor, with the coal-to-liquids language removed, a motion to recommit the conference report with instructions using the same language as the motion to instruct, which passed 258–167 just two days before, was voted down 199–227. In two days, months of House precedent was ignored. I am not sure why, but over 50 of my colleagues switched their vote. I am grateful that today's hearing will allow us to examine and discuss the implications of federal support for research and development into the potential for domestic energy to be produced from coal-to-liquids.

In addition to the actions taken by the House, on June 20, 2007, a new congressionally mandated report from the National Research Council of the National Academies of Science was released. It recommends an increase of about $144 million annually in new federal funding in a variety of areas to ensure that coal is mined efficiently, safely, and in an environmentally responsible manner. One of the areas the report recommended requires additional study is estimates of the amount, location, and quality of mineable coal. The report indicated that there is enough coal at current rates of production to meet anticipated needs through 2030, and probably enough for 100 years. However, the report concluded that it is not possible to confirm the often-quoted assertion based upon estimates from the mid-1970's that there is a sufficient supply for the next 250 years. This range of estimates from 100 years to 250 years is based upon current use rates. It does not take into account the increased use rate that would result from coal-to-liquids technologies. The report noted that actual usage rates of coal could vary considerably depending upon any regulatory carbon constraints imposed by federal legislation or international agreements.

I look forward to the testimony of today's witnesses about the pros and cons of proposals concerning the production of synthetic transportation fuels from coal and the appropriate role of Federal Government involvement in any such efforts.

Chairman LAMPSON. At this time I would like to introduce our witnesses. We have Dr. Robert Freerks, Director of the—of Product Development with Rentech Corporation, Dr. James T. Bartis is a Senior Policy Researcher at the RAND Corporation, Dr. David G. Hawkins is the Director of the Climate Center at the National Resources Defense Council. Dr. Joseph Romm is a Senior Fellow with the Center for American Progress. Dr. Romm is also former Acting Assistant Secretary of the Office of Energy Efficiency and Renewable Energy during the Clinton Administration. Dr. Richard D. Boardman heads the Security, the Secure Energy Initiative at the Idaho National Laboratory, Department of Energy, and I was looking for my friend from Utah, Mr. Matheson, to introduce our last witness, Mr. Ward, but Mr. Matheson didn't get—come in and say nice things. So, Mr. Ward, John Ward, is the Vice-President for Marketing and Governmental Affairs at Headwaters, Inc.

And we welcome all of you. And our witnesses should know that spoken testimony is limited to five minutes each, after which the

Members of the Committee will have five minutes to each ask questions.

And we will begin with Dr. Freerks.

STATEMENT OF DR. ROBERT L. FREERKS, DIRECTOR, PRODUCT DEVELOPMENT, RENTECH, INC.

Dr. FREERKS. Thank you. Good morning. I am Dr. Robert Freerks, Director of Product Development for Rentech. I am a synthetic organic chemist with 26 years experience in the science of fuels and for the past eight years have been working on producing synthetic jet fuel and diesel fuel, utilizing the Fischer-Tropsch (F–T) process.

Rentech is one of the world's leading developers of Fischer-Tropsch technologies with 25 years experience building and operating five plants. Our plant designs are a straightforward application of proven commercial components. The process first takes any carbon source, gasifies it to producing gas, which is fed to Fischer-Tropsch's reactor, and the raw F–T products are processed into chemical feedstocks, diesel, jet fuel, and NAPTHA.

The process captures CO_2 and other contaminants at several stages. F–T can be a significant element of the solution for the dual energy challenges facing America, dependence on imported crude oil, and the need to reduce our greenhouse gas emissions. Given the abundance of domestic feedstocks and the proven track record of the technology, F–T fuels can greatly help reduce oil imports and Rentech will lead the way.

Along with our commitment to energy security, Rentech is dedicated to reducing greenhouse gas emissions. CO_2 capture is inherent in the Rentech process, although the only obstacle to significant carbon emissions reductions is sequestration. Rentech has teamed with Denbury Resources, a company that is leading in the way on CO_2 sequestration and enhanced oil recovery (EOR).

When used for EOR, CO_2 from the production of one barrel of F–T fuel yields an additional barrel of oil for marginal oil fuels, resulting in a two-for-one domestic energy benefit. Rentech fuels are the cleanest liquid transportation fuels available.

As you can see from the containers in front of you, the fuels are clearer, they smell like wax, they contain essentially no sulfur and aromatics, they are non-toxic, biodegradable, and completely compatible with the fuel distribution system in engines.

The DOD, a leader in this area, has found F–T fuels to meet virtually all of their environmental and performance requirements, including significant particulate matter reductions up to 96 percent, reduce CO_2 emissions, and higher performance in advanced aircraft.

Last month the Air Force certified its entire B–52 fleet to run on a 50/50 blend of F–T jet fuel with conventional jet fuel, and we look forward to 2011, when that certification is extended to the entire fleet.

Today the barriers to building large scale coal and pet coke fed F–T facilities are purely financial. Oil price volatility continues to discourage potential F–T investors. Congress should enact policies to help reduce risk and encourage investment in these plants. And

I refer to my written statement for our recommendations including a regulatory and legal framework for CO_2 sequestration.

Also, as our nation enters into a regulatory regime for managing CO_2 emissions, it will be critical that the system established to account for man-made CO_2 is beyond reproach. This committee should take the leadership role in forcing the development of a modern, comprehensive, and universal model for assessing the life cycle greenhouse gas emissions for all fuels. Such a life cycle analysis should consider the latest production technologies and processes, the energy inputs throughout the production of the raw material, and through the distribution to the point of sale, including those of imported oil and other fuels and the emissions associated with their use.

What I have discussed so far is the current state of coal-to-liquid (CTL) technology. What I want to discuss next is the future.

As I described above, the first step in our process is gasification of the feedstock to produce gas for use in our F–T reactor. Rentech is in the early stages of developing the next generation of our process, biomass to liquids (BTL). Unlike CTL, which has been utilized commercially for decades, commercialization of BTL faces near-term hurdles. Current biomass gasification technology is not nearly as advanced as that of coal gasification. Most manufacturers are just now investigating the ability of their systems to accept biomass along with coal.

Advancing new biomass gasification and co-feed technologies could be greatly expedited with federal support. Biomass gasification works, and it is our objective to integrate it into our production process in progressively-increasing percentages. But for a company such as Rentech or any of the other U.S.-based F–T fuel developers and their investors, such risks are not financeable at this time.

Congress can help advance the technology of BTL through the establishment of a loan or grant program to allow commercial operators to acquire gasifiers that can be dedicated to testing various forms of biomass over extended periods and growing season.

Once biomass has been proven as a viable commercial feedstock for F–T plants and the plants are connected to carbon sequestration opportunities such as EOR, as is our Natchez plant, then it is entirely realistic to envision a process that absorbs CO_2 from the atmosphere and stores it underground. This would move transportation fuels and coal from being a producer of greenhouse gasses to being a net part of the solution. We view this as the game changer, not only for Rentech, but for our nation.

Thank you very much for the opportunity to address the Subcommittee today, and I look forward to answering any questions.

[The prepared statement of Dr. Freerks follows:]

PREPARED STATEMENT OF ROBERT L. FREERKS

Honorable Members of the House of Representatives Committee on Science and Technology, Subcommittee on Energy and Environment, thank you for the opportunity to testify today on the benefits and challenges of producing fuels from coal. I am Dr. Robert Freerks, Director of Product Development for Rentech, Inc. For the past eight years I have been working on processes for the production of synthetic jet and diesel fuels from alternative resources utilizing the Fischer-Tropsch (F–T) process. My educational background is in synthetic organic chemistry and I have 26 years experience in fuels and related technologies.

Rentech is one of the world's leading developers of Fischer-Tropsch technologies. As such, it is the company's vision to develop technology and projects to transform underutilized hydrocarbon resources such as coal, petroleum coke, remote or stranded natural gas and biomass and municipal waste into valuable clean fuels and chemicals that will help accommodate our nation's growing energy needs. Our company has been in the business of developing alternative and renewable energy technologies for more than 25 years, having been initially affiliated with the Solar Energy Research Institute which became the National Renewable Energy Laboratory in Golden, Colorado. Rentech's focus is on the technology for converting synthesis gas, carbon monoxide and hydrogen, into ultra clean synthetic diesel and jet fuels via the Fischer-Tropsch process followed by hydroprocessing.

The goal of our efforts is to demonstrate the viability of this technology for diverse alternative feedstock materials into fungible transportation fuels in volumes great enough to reduce importation of crude oil and refined fuel products. Currently the United States imports approximately 65 percent of our crude oil and fuel products. Conversion of biomass into first generation biofuels is estimated by EIA to provide only 11.2 billion gallons in 2012 per year or 458,000 barrels of oil equivalent per day, which would account for about 2.3 percent of today's consumption of 20 million barrels per day. The largest plants will have a capacity of no more than about 7,000 barrels per day. Rentech's first plant will produce 30,000 barrels each day or 460 million gallons per year, and it will be scalable to more than 80,000 barrels per day.

Rentech is well aware of the dual energy problems facing America: The need for independence from imported crude oil; and the need to reduce the greenhouse gas (GHG) footprint of these fuels. First I'd like to briefly address energy security. As a company we believe that the U.S. cannot achieve energy independence without utilization of its many diverse natural resources, including both renewable and fossil fuels. Given the current level of our dependence upon imported oil we must consider all realistic options in solving this problem. But achieving this goal will take guidance and support from the Federal Government to protect investors from the consequences market manipulation by the oil cartel. We must remember that the oil markets are not free markets and it is not unreasonable to believe that if we begin to succeed in ending our addiction to foreign oil, the nations that produce it will try to undermine our efforts at energy independence by cutting prices. Relying on affordable, abundant domestic coal helps to mitigate strategic concerns, but does not eliminate the risk of a price cut intended sustain our addiction to imported oil.

The benefits to the U.S. in terms of energy security, balance of payments, and the establishment of the new CTL technology base with an associated increase in jobs will be substantial and obvious. Projects that Rentech is developing are located in economically challenged areas such as our proposed plant in Natchez, Mississippi, and our conversion of a fertilizer plant in East Dubuque, Illinois. Our hope is that Washington will make a long-term commitment to a broad suite of alternative energy solutions; including those utilizing our abundant coal reserves, but that encourages cooperative efforts across segments of the alternative fuels industry.

Second, Rentech is committed to developing and deploying technologies and processes that reduce the GHG emissions associated with both the production and use of our fuels. We have assembled a Carbon Leadership Team to address the overall carbon footprint of fuels production using Rentech's F–T technology. This team which includes all senior executives, staff scientists and engineers has committed the company to being a leader in reduction of carbon dioxide emissions from our projects. A CO_2 solution is a key decision criterion in advancing a project. The Rentech plant design already incorporates carbon capture as an integral part of the process, the only obstacle to significant carbon emissions reductions is sequestration of the captured carbon dioxide.

But our commitment to CO_2 management does not stop at the fence. Rentech has already established relationships with companies that transport and sequester CO_2 using existing Enhanced Oil Recovery (EOR) technologies that have been proven for over 20 years. EOR in conjunction with F–T fuels production will increase available energy by approximately one barrel of crude for every barrel of F–T fuel produced, increasing oil production from existing North American fields and further improving our nation's energy security. Pipelines already exist for the transportation of CO_2 in several areas of the country and plans are being formulated to extend pipeline capabilities to cover significant areas of the central and eastern U.S. Rentech has partnered with Denbury Resources to supply CO_2 to several locations for EOR sequestration. One sequestration site is the Gulf Coast Stacked Storage project in Cranfield, Mississippi, part of the Southeast Regional Carbon Sequestration Partnership (SECARB), a public-private partnership dedicated to the development and deployment of carbon sequestration solutions.

But the benefits of Rentech's fuels are not limited to CO_2. Rentech fuels will be the cleanest liquid transportation fuels available. F–T diesel and jet fuel are pure paraffinic hydrocarbons. This means that they inherently contain essentially no sulfur and aromatics, two fuel components that have long been the focus of federal and State environmental protection policies. The fuels are clear, non-toxic, biodegradable and completely fungible with current fuels and fuel transportation infrastructure. This means that no changes are needed to fuel distribution pipelines or engines to use F–T diesel and jet fuel. *(A comparison of the life cycle CO_2 emissions from diesel fuels produced from coal to diesel fuels produced from several different qualities of crude oil is shown below as Figure 1.)*

The Department of Defense has been a leader in advancing the development of a U.S.-based Fischer-Tropsch fuels industry. As part of several conjoined programs, the Department is seeking to encourage the development of a domestic alternative fuels industry that can provide a reliable source of fuel for their aircraft, tanks, ships and other vehicles while reducing emissions. For the sake of simplifying logistics, these initiatives also aim to reduce the multiple types of fuels that our military must carry to the battlefield—approximately nine. This new fuel also must be capable of being stored, transported and distributed using existing infrastructure. Only fuels produced using the Fischer-Tropsch process are able to meet all of these requirements.

Through the Assured Fuels Initiative the Air Force has tested F–T jet fuel in multiple applications from a diesel engine powered HMMWV (Hummer) to a B–52 bomber. Last month, the Air Force certified its entire B–52 fleet to fly on a 50/50 blend of F–T jet fuel and conventional jet fuel, and is progressing on extending that certification to all its aircraft by 2011. *(See Figure 2 below for a comparison of particulate emissions from a turbine engine using blends of conventional and synthetic Fischer-Tropsch jet fuels. Figure 3 illustrates the DOD view of the future use of F–T jet fuel in a multitude of applications.)*

Commercial aviation is also progressing towards full acceptance of F–T jet fuel in general aviation aircraft. The Federal Aviation Administration is supporting the Commercial Aviation Alternative Fuels Initiative (CAAFI) which will oversee the efforts to approve the use of blends of F–T fuel with conventional jet fuel. This fuel is already in use in South Africa and all planes flying out of Johannesburg International Airport have been using a blend of F–T jet fuel and conventional jet fuel for seven years, including Delta Air Lines that recently initiated service from Atlanta.

F–T fuels offer numerous benefits for aviation users. The first is an immediate reduction in particulate emissions. F–T jet fuel has been shown in laboratory combustors and engines to reduce PM emissions by 96 percent at idle and 78 percent under cruise operation. Validation of the reduction in other turbine engine emissions is still under way. Concurrent to the PM reductions is an immediate reduction in CO_2 emissions from F–T fuel. F–T fuels inherently reduce CO_2 emissions because they have higher energy content per carbon content of the fuel, and the fuel is less dense than conventional jet fuel allowing aircraft to fly further on the same load of fuel.

The fuel also offers increased turbine engine life through lowered peak combustion temperature. This reduces stress on hot components in the turbine engine thereby increasing the life of those components. Fuels that burn cooler may also help to reduce the heat signature of aircraft, making them less vulnerable to infrared missile attacks. *(Figure 3 shows some of the many applications for F–T jet fuel in military equipment ranging from tanks to fuel cells to spacecraft.)* Also critical to meeting the needs of aviation, F–T fuels are truly "drop-in replacements" for their petroleum-based counterparts, requiring no new pipelines, storage facilities, or engine modifications, barriers that have stalled other alternative aviation fuels programs.

Another advantage to F–T fuels is the maturity of the technology. Rentech's plant designs are a relatively straight forward application of existing, proven commercial components that can provide reliable production of liquid hydrocarbon fuel and chemical products. The process first takes a carbon source such as coal, gasifies it to carbon monoxide and hydrogen (known as synthesis gas or syngas), removes contaminants from this syngas including carbon dioxide, and captures energy from that process for electricity production. The purified syngas is then fed to a Fischer-Tropsch reactor where the carbon monoxide and hydrogen are converted to hydrocarbons. At this stage, additional carbon dioxide is captured from the recycle stream and prepared for sequestration. The raw F–T products are further processed into chemical feedstocks, diesel, jet fuel and naphtha using conventional refining and distillation technologies. *(See Figure 4 for a simplified process flow diagram.)*

Today, the barriers to building large scale commercial F–T facilities that can cut into the volume of imported oil are purely financial. The history of the energy busi-

ness, particularly the oil industry, is marked by volatility. Investors have long memories and, as has been said before, "capital is cowardly." Many who are interested in investing in alternative energy production are looking to Washington to provide some level of certainty. The cost of a 30,000 to 40,000 barrel per day F–T plant is estimated in the $3 to $6 billion range, numbers that are often associated with large traditional refineries or power plants, not alternative energy production.

Federal policies and programs that can help to provide the needed certainty can take several forms. The first, and most natural, would be for the Department of Defense to enter into long-term supply contracts with F–T fuel producers. There are several bipartisan proposals to enable this, including extension of the Department's contracting authority from its current five-year limit to 25 years. Next would be the establishment of a program similar to that proposed by Representatives Boucher and Shimkus to create a "price collar" program which would protect producers from a dramatic drop in oil prices and taxpayers through a revenue sharing mechanism when prices exceed a certain level.

Extending the extending the existing alternative fuels excise tax credit, which covers F–T fuels and is set to expire in the fall of 2009, to 2020 would also provide a level of protection for investors from potential OPEC price manipulation intended to undermine U.S. alternative energy programs.

The next area that the Federal Government can assist in is providing regulatory certainty with respect to CO_2 sequestration. The DOE should encourage the exploration of options for managing industrial CO_2 and the Federal Government should assume responsibility for geologically sequestered CO_2.

As our nation enters into a regulatory regime for managing CO_2 emissions, it will also be critical that the system that is established to account for manmade CO_2 is beyond reproach. This committee should take a leadership role in forcing the development of a modern, comprehensive and universal model for assessing the life cycle greenhouse gas emissions for all fuels. Such a life cycle analysis should consider the latest production technologies and processes, the energy inputs throughout production of the raw material through fuel distribution to the point of sale, including those of imported oil and other fuels, and the emissions associated with its use. This model should be applicable across all fuel types and not tailored to consider only the emissions of a few.

With the exception of improving life cycle analysis science, all of the incentives that I have listed are to advance deployment of F–T technology rather than to advance the state of it. To repeat, our current hurdles are financial much more than technical. But as I described above, the first step in our process is the gasification of a feedstock, either coal or petroleum coke, to produce synthetic natural gas for use in our F–T reactor. While coal and pet coke are the feedstock of choice today that does not forever have to be the case. As a company we are agnostic on what feedstock we use, as long as it works. Rentech is in the early stages of developing the next generation of our process—biomass-to-liquids. Unlike CTL, which has been utilized commercially for decades, commercialization of BTL faces near-term hurdles. Current gasification technology manufacturers and operators have limited or no experience with biomass gasification on a commercial scale. Some are just now investigating their ability to feed biomass along with coal and there is no estimate yet available for how much biomass could be fed without upsetting the design of the gasifier.

Advancing new biomass gasification technologies could be greatly expedited with federal support to attract investment. Biomass gasification works and it is our objective, moving forward, to prove technologies and processes that allow for an increasing percentage of our feedstock to come from biomass. Congress can help advance the technology of BTL through the establishment of loan or grant programs expressly to allow commercial operators to acquire gasifiers that can be dedicated to testing various forms of biomass over extended periods and growing seasons. Coupled with carbon sequestration this holds great potential to help move fuels production from a process that emits CO_2 to one that absorbs CO_2. But for a company such as Rentech, or any of the other U.S. based F–T fuels developers and their investors, such risks are not financeable at this time.

There is also a role for the Federal Government in assessing the regional availability of various biomass supplies. It is currently not known how much biomass will be available in any given location without disrupting the ecology of that area or impacting food supply. It is always assumed that biomass is readily available, but few studies exist to show that supplying biomass to a major fuels production facility can be accomplished on a sound economic basis and that this supply can be sustained for an extended time period. Congress should study of the availability and cost of biomass in several areas of the U.S. where CTL plants could be located. The sustainable availability of biomass at some level is needed if biomass is to be used to

reduce the overall carbon footprint of a CTL facility. There have been assertions that specific levels of biomass co-feeds are possible. These will remain academic theories until these questions are answered.

Once biomass has been proven as a viable commercial feedstock for F–T plants and plants are connected to carbon sequestration opportunities such as EOR, as is our Natchez plant, then it is entirely realistic to envision a process that extracts CO_2 from the atmosphere and stores it underground. This would move transportation fuels from being a contributor to global warming to being part of the solution. We view this as a “game changer” not only for Rentech but for our nation.

Thank you very much for the opportunity to address the Subcommittee today and I look forward to answering any questions you may have for me.

Figures

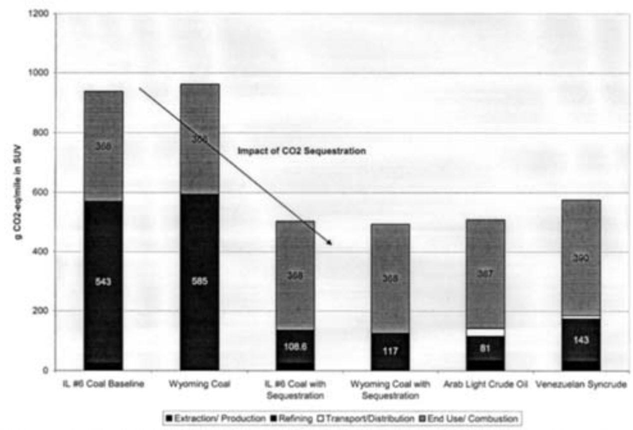

Figure 1. Full lifecycle GHG emissions for CTL F-T fuels without and with sequestration compared to conventional Arabian Light and Venezuelan Crude derived diesel based on NETL analysis by Marano/Ciferno, 2001

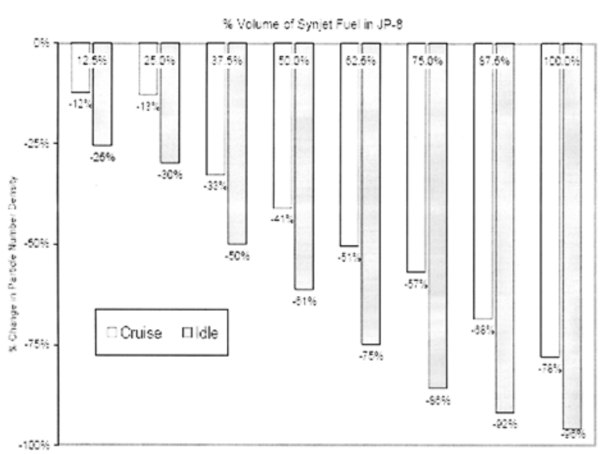

Figure 2. Reductions in particle number density emissions from T63 engine as a function of synthetic fuel in JP-8

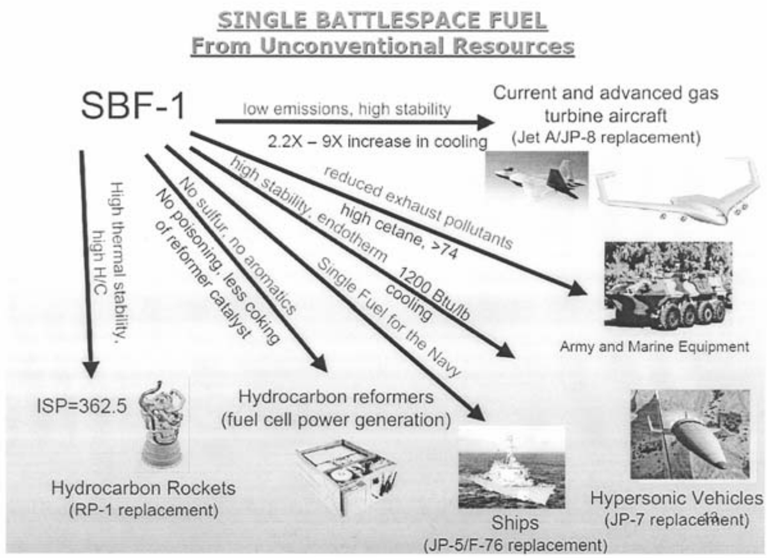

Figure 3. DOD Single Battlefield Fuel concept for Fischer-Tropsch jet fuel.

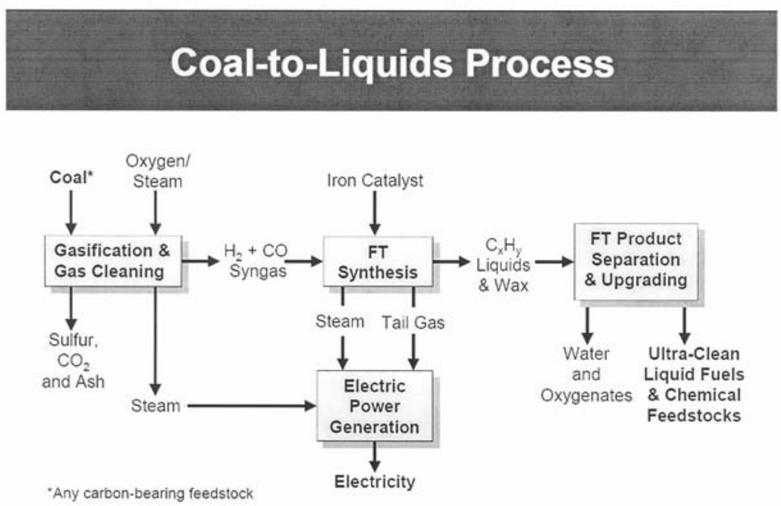

Figure 4. Process Flow Diagram for CTL facility.

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Chairman LAMPSON. Thank you, Dr. Freerks.

Mr. Ward.

STATEMENT OF MR. JOHN N. WARD, VICE PRESIDENT, MARKETING AND GOVERNMENT AFFAIRS, HEADWATERS INCORPORATED

Mr. WARD. Thank you, Mr. Chairman. Members of the Committee, I am John Ward, Vice President of Headwaters Incorporated, on whose behalf I am testifying today. I am the Immediate Past President of the American Coal Council and also serve on the National Coal Council as appointed by the Secretary of Energy.

Headwaters is a member of the Coal-to-Liquids Coalition, which is a broad group of industry, labor, energy technology developers, and consumer groups. This coalition is interested in strengthening U.S. energy independence through the greater utilization of domestic coal to produce clean transportation fuels.

The prospect of making liquid transportation fuels from America's abundant coal resources has received significant attention in recent months, and as with any high-profile policy debate, this means many misconceptions have arisen. It may be best at this point to summarize what coal-to-liquids is by pointing out what it is not.

First of all, coal-to-liquids is not a new kind of fuel. Any liquid fuel product that can be made from crude oil can be made from coal. Products from coal-to-liquids plants include high quality gasoline, diesel fuel, and jet fuel that can be used in the existing engines without modification of those engines and can be distributed through out existing fuel distribution systems.

Second of all, coal-to-liquids is not dirty. In fact, fuels produced by today's coal-to-liquids processes are exceptionally clean when compared to today's petroleum-derived fuels. Coal-to-liquid fuels contain substantially no sulfur. They also exhibit lower particulate and carbon monoxide emissions. These fuels also contribute less to the formation of nitrogen oxides than petroleum-derived fuels, and they are readily biodegradable.

As for greenhouse gas emissions, coal-to-liquids refineries generate carbon dioxide in highly-concentrated form, allowing for carbon capture and storage. Coal-to-liquids refineries with carbon di-

oxide capture and storage can produce fuels with life cycle greenhouse gas emissions profiles that are as good as or better than the petroleum fuels that they replace.

And finally, coal-to-liquids is not strictly a research and development effort. The term "coal-to-liquids" refers to a broad class of technologies for making liquid transportation fuels from coal. Many of these technologies have been known for decades. Many are being deployed at commercial scale in other parts of the world. And likewise, carbon capture and storage technologies are currently being practiced at commercial scale for enhanced oil recovery operations in many locations around the globe.

As the Federal Government considers measures to support coal-to-liquids, it is important to provide two different types of support.

First, commercialization incentives are needed to speed the commercial deployment of coal-to-liquids facilities in the United States with the goal of increasing our nation's energy security.

Second, research support is needed to continue to improve the efficiency and environmental performance of coal-to-liquids technologies, with the goal of making this already clean resource even cleaner.

Specific areas where continued research and development support would be beneficial include: number one, utilization of biomass as a strategy for reducing greenhouse gas emissions.

Number two, improving life cycle assessment tools for determining greenhouse gas emissions profiles for coal-to-liquids facilities when compared to other fossil fuel energy sources.

And number three, expanding methods of carbon capture and storage beyond the currently available opportunities in the area of enhanced oil recovery.

The advantages to developing a coal-to-liquids capability in the United States are numerous, and some of the dollars we now send overseas to buy oil would be kept at home to develop American jobs, utilizing American energy resources. We would expand and diversify our liquid fuels production and refining capacity using technologies that are already proven.

We would produce clean-burning fuels that can be distributed through our existing pipelines and service stations to fuel our existing vehicles with no modifications to their engines. We would take a real and immediate step toward greater energy security.

Thank you for the invitation to testify and your interest in this important topic. I would be happy to answer any questions.

[The prepared statement of Mr. Ward follows:]

PREPARED STATEMENT OF JOHN N. WARD

Improving America's Energy Security Through Liquid Fuels Derived from Coal

Thank you Mr. Chairman. Honorable Members of the Committee, I am John Ward, Vice President of Headwaters Incorporated, on whose behalf I am testifying today. I also serve as Immediate Past President of the American Coal Council and as a member of the National Coal Council as appointed by the Secretary of Energy.

Headwaters Incorporated is a New York Stock Exchange company that provides an array of energy services. We are a leading provider of pre-combustion clean coal technologies for power generation, including coal cleaning, upgrading and treatment. We are the Nation's largest post-combustion coal product manager, recycling coal

ash from more than 100 power plants nationwide. We have built a large construction materials manufacturing business and incorporated coal ash in many of our products. We are currently commercializing technologies for upgrading heavy oil and have entered the biofuels market by constructing our first ethanol production facility utilizing waste heat from an existing coal fueled power plant in North Dakota. Headwaters is also active as both a technology provider and a project developer in the field of coal-to-liquid fuels.

Headwaters is a member of the Coal-to-Liquids Coalition—a broad group of industry, labor, energy technology developers and consumer groups. This coalition is interested in strengthening U.S. energy independence through greater utilization of domestic coal to produce clean transportation fuels.

Summary of Testimony

The prospect of making liquid transportation fuels from America's abundant coal resources has received significant attention in recent months. As with any high profile policy debate, this means that many misconceptions have arisen. It may be best, at this point, to summarize what "Coal-to-Liquids" is by pointing out what it is not:

- Coal-to-liquids is *not* a new kind of fuel. Any liquid fuel product that can be made from crude oil can be made from coal. Products from coal-to-liquids plants include high quality gasoline, diesel fuel, and jet fuel that can be used in existing engines without making any modifications to the engines or distribution systems for the fuel.
- Coal-to-liquids is *not* dirty. In fact, fuels produced by coal-to-liquids processes are exceptionally clean when compared to today's petroleum-derived transportation fuels. Coal-to-liquids fuels contain substantially no sulfur and also exhibit lower particulate and carbon monoxide emissions. These fuels also contribute less to the formation of nitrogen oxides than petroleum derived fuels and they are readily biodegradable. As for greenhouse gas emissions, coal-to-liquids refineries generate carbon dioxide in highly concentrated form allowing carbon capture and storage. Coal-to-liquids refineries with carbon dioxide capture and storage can produce fuels with life cycle greenhouse gas emission profiles that are as good as or better than that of the petroleum-derived products they replace.
- Coal-to-liquids is *not* strictly a research and development effort. The term "coal-to-liquids" refers to a broad class of technologies for making liquid transportation fuels from coal. Many of these technologies have been known for decades and many are being deployed at commercial scale around the world. Likewise, carbon capture and storage technologies are currently being practiced at commercial scale for enhanced oil recovery operations.

As the Federal Government considers measures to support coal-to-liquids, it is important to provide two different types of support:

- Commercialization incentives are needed to speed the commercial deployment of coal-to-liquids facilities in the United States with the goal of increasing our nation's energy security.
- Research support is needed to continue to improve the efficiency and environmental performance of coal-to-liquids technologies with the goal of making this already clean resource even cleaner.

Specific areas where continued research and development support would be beneficial include:

- Utilization of biomass as a strategy for reducing greenhouse gas emissions.
- Improving life cycle assessment tools for determining greenhouse gas emissions profiles for coal-to-liquids facilities when compared to other fossil fuel energy sources.
- Expanding methods of carbon capture and storage beyond currently available opportunities in the area of enhanced oil recovery.

Why Coal-to-Liquids?

It's easy to see why coal-to-liquids is attracting so much attention these days. In the President's words, the United States is addicted to oil. U.S. petroleum imports in 2005 exceeded $250 billion. In the past two years, natural disasters have disrupted oil production and refining on the U.S. gulf coast. Political instability in the Middle East and other oil producing regions is a constant threat. Fuel prices have rapidly escalated along with world oil prices that are reaching levels unseen since the 1970s energy crisis.

The situation is not likely to get much better in the future. Global oil demand was 84.3 million barrels per day in 2005. The United States consumed 20.7 million barrels per day (24.5 percent) and imported 13.5 million barrels per day of petroleum products. Worldwide demand for petroleum products is expected to increase 40 percent by 2025 largely due to growing demand in China and India. World oil production could peak before 2025. Most of the remaining conventional world oil reserves are located in politically unstable countries.

In contrast, coal remains the most abundant fossil fuel in the world and the United States has more coal reserves than any other country. With coal-to-liquids technology, the United States can take control of its energy destiny. Any product made from oil can be made from coal. At today's oil prices, coal-to-liquids is economical and has the power to enhance energy security, create jobs here at home, lessen the U.S. trade deficit, and provide environmentally superior fuels that work in today's vehicles. By building even a few coal-to-liquids plants, the U.S. would increase and diversify its domestic production and refining base—adding spare capacity to provide a shock absorber for price volatility.

Coal-to-Liquids Historical Perspective

Headwaters and its predecessors have been engaged in coal-to-liquids technologies since the late 1940s. Our alternative fuels division is comprised of the former research and development arm of Husky Oil and holds approximately two dozen patents and patents pending related to coal-to-liquids technologies.

The founders of this group included scientists engaged in the Manhattan Project during World War II. After the conclusion of the war, these scientists were dispatched to Europe to gather information on technologies used by Germany to make gasoline and diesel fuel from coal during the war.

In the late 1940s, this group designed the first high temperature Fischer-Tropsch conversion plant which operated from 1950 to 1955 in Brownsville, Texas. It produced liquid fuels commercially at a rate of 7,000 barrels per day. Why did it shut down? The discovery of cheap oil in Saudi Arabia.

The Arab oil embargo of 1973 reignited interest in using domestic energy resources such as coal for producing transportation fuels. From 1975 to 2000, Headwaters researchers were prime developers of direct coal liquefaction technology. This effort, which received more than $3 billion of federal research funding, led to the completion of an 1,800 barrels per day demonstration plant in Catlettsburg, Kentucky. Why did deployment activities cease there? OPEC drove oil prices to lows that left new technologies unable to enter the market and compete.

Today, our nation finds itself in another energy crisis. Oil costs more than $70 per barrel and comes predominantly from unstable parts of the world. There is little spare production and refining capacity and our refineries are concentrated in areas susceptible to natural disasters or terrorist attacks. And once again, our nation is considering coal as a source for liquid transportation fuels. The question is: What can we do this time to ensure that the technologies are fully deployed?

Coal-to-Liquids Technology Overview

From a product perspective, coal-to-liquids refineries are very similar to petroleum refineries. They make the same range of products, including gasoline, diesel fuel, jet fuel and chemical feedstocks. These fuels can be distributed in today's pipelines without modification. They can be blended with petroleum derived fuels if desired. They can be used directly in today's cars, trucks, trains and airplanes without modifications to the engines.

From a production perspective, coal-to-liquids refineries utilize technologies that have been commercially proven and are already being deployed in other parts of the world. Two main types of coal-to-liquids technologies exist. Indirect coal liquefaction first gasifies the solid coal and then converts the gas into liquid fuels. Direct coal liquefaction converts solid coal directly into a liquid "syncrude" that can then be further refined into fuel products.

To understand how coal-to-liquids technologies work, it is helpful to focus on the role of hydrogen in fuels. Coal typically contains only five percent hydrogen, while distillable liquid fuels such as petroleum typically contain 14 percent hydrogen. The hydrogen deficit can be made up in two different ways:

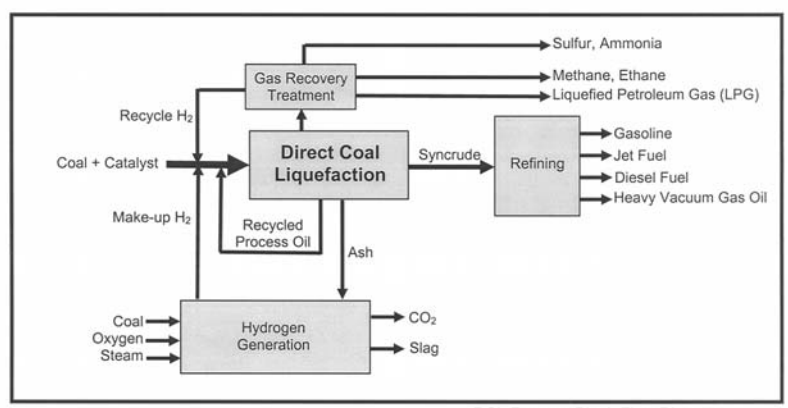
Direct Coal Liquefaction (DCL)
Coal + Catalyst + Hydrogen (H_2) → Hydrocarbons (C_xH_y)

or

Indirect Coal Liquefaction (ICL)
1. Gasification: Coal + Oxygen + Steam → Syngas (H_2 + CO)
2. FT Synthesis: H_2 + CO + Catalyst → Hydrocarbons (C_xH_y)

Direct Coal Liquefaction

Direct coal liquefaction involves mixing dry, pulverized coal with recycled process oil and heating the mixture under pressure in the presence of a catalyst and hydrogen. Under these conditions, the coal transforms into a liquid. The large coal molecules (containing hundreds or thousands of atoms) are broken down into smaller molecules (containing dozens of atoms). Hydrogen attaches to the broken ends of the molecules, resulting in hydrogen content similar to that of petroleum. The process simultaneously removes sulfur, nitrogen and ash, resulting in a synthetic crude oil (syncrude) which can be refined just like petroleum-derived crude oil into a wide range of ultra-clean finished products.



DCL Process Block Flow Diagram

Direct coal liquefaction originated in Germany in 1913, based on work by Friedrich Bergius. It was used extensively by the Germans in World War II to produce high octane aviation fuel. Since that time, tremendous advancements have been made in product yields, purity and ease of product upgrading.

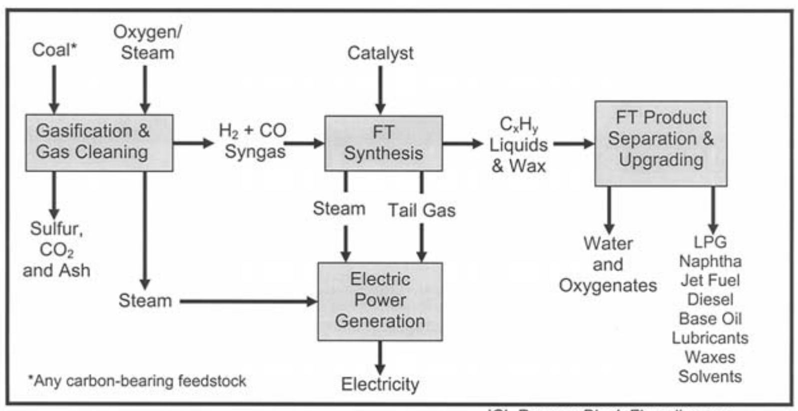
From 1976 to 2000, the U.S. Government invested approximately $3.6 billion (1999 dollars) on improving and scaling up direct coal liquefaction. During this time, pilot and demonstration facilities ranging from 30 to 1800 barrels per day of liquid fuel were built and operated in the United States. The end result of this effort is the HTI DCL process developed by Hydrocarbon Technologies Incorporated, a subsidiary of Headwaters.

In June 2002, the largest coal company in China (Shenhua Group) agreed to apply the HTI technology for the first phase of a three-phase multi-billion dollar direct coal liquefaction project. The Shenhua direct coal liquefaction facility in Inner Mongolia is currently under construction and is scheduled to startup in 2008. The first phase, as currently configured, has a capacity of 20,000 barrels per day.

Additional direct coal liquefaction projects are currently being studied or planned in India, the Philippines, Mongolia and Indonesia. The Philippines project is based on hybrid technology utilizing both direct and indirect coal liquefaction.

Indirect Coal Liquefaction

Indirect coal liquefaction is a two-step process consisting of coal gasification and Fischer-Tropsch (FT) synthesis. Coal is gasified with oxygen and steam to produce a synthesis gas (syngas) containing hydrogen and carbon monoxide. The raw syngas is cooled and cleaned of carbon dioxide and impurities. In the F–T synthesis reactor, the cleaned syngas comes in contact with a catalyst that transforms the diatomic hydrogen and carbon monoxide molecules into long-chained hydrocarbons (containing dozens of atoms). The F–T products can be refined just like petroleum-derived crude oil into a wide range of ultra-clean finished products.



ICL Process Block Flow diagram

Indirect coal liquefaction was developed in Germany in 1923 based on work by Drs. Franz Fischer and Hans Tropsch. During World War II, the technology was used by Germany to produce 17,000 barrels per day of liquid fuels from coal.

In 1955, Sasol constructed an indirect coal liquefaction plant at Sasolburg, South Africa. Additional indirect coal liquefaction plants were constructed by Sasol in Secunda, South Africa. Today Sasol produces the equivalent of 150,000 barrels per day of fuels and petrochemicals using its technology—supplying approximately 30 percent of South Africa's liquid transportation fuels from coal. Technologies for indirect coal liquefaction are also being developed and deployed by Headwaters, Shell, Syntroleum and Rentech.

Indirect coal liquefaction projects are currently being studied or planned in China, Philippines, Germany, Netherlands, India, Indonesia, Australia, Mongolia, Pakistan and Canada. In the United States, indirect coal liquefaction projects are being considered in Alaska, Arizona, Colorado, Illinois, Indiana, Kentucky, Louisiana, Mississippi, Montana, North Dakota, Ohio, Pennsylvania, Texas, West Virginia and Wyoming,

Comparison of Direct and Indirect Coal Liquefaction Products

One of the main differences between direct and indirect coal liquefaction is the quality of the raw liquid products. Direct coal liquefaction raw products contain more ring structure. Therefore direct coal liquefaction naphtha is an excellent feedstock for production of high-octane gasoline, while direct liquefaction distillate requires considerable ring opening (mild hydrocracking) to generate on spec diesel fuel. On the other hand, the straight-chain structure hydrocarbons produced by indirect coal liquefaction technology results in high-cetane diesel fuel, but indirect liquefaction naphtha needs substantial refining (isomerization and alkylation) to produce on spec gasoline.

Both processes produce low-sulfur, low-aromatic fuels after the refining step Direct and indirect coal liquefaction can be combined into a hybrid plant that produces both types of products that can be blended into premium quality gasoline, jet fuel and diesel with minimum refining.

	Direct	Indirect	EPA 2006 Diesel Spec
Distillable product mix	65% diesel 35% naphtha	65 -80% diesel 20-35% naphtha	
Diesel cetane	42-47	70-75	>40
Diesel sulfur	<5 ppm	<1 ppm	<15 ppm
Diesel aromatics	4.8%	<4%	<35%
Diesel specific gravity	0.865	0.780	
Naphtha octane (RON)	>100	45-75	
Naphtha sulfur	<0.5 ppm	Nil	
Naphtha aromatics	5%	2%	
Naphtha specific gravity	0.764	0.673	

Indirect coal liquefaction plants usually include combined-cycle electric power plants because they produce a substantial amount of steam and fuel gas that can be used to generate electricity. Direct coal liquefaction plants produce less steam and fuel gas, so they can be designed to purchase electricity, be self-sufficient in electricity generation or generate excess power depending on the local market conditions.

Direct coal liquefaction plants produce more liquid fuel per ton of coal than indirect plants. However, indirect plants are better suited for polygeneration of fuels, chemicals and electricity than direct plants.

The preferred feedstock for direct coal liquefaction plants is low-ash, sulfur-bearing, sub-bituminous or bituminous coal. Indirect plants have greater feedstock flexibility and can be designed for almost any type of coal ranging from lignite to anthracite.

Coal-to-Liquids Environmental Profile

Fuels produced by coal-to-liquids processes are usable in existing engines without modifications and can be distributed through existing pipelines and distribution systems. Nevertheless, they are exceptionally clean when compared to today's petroleum-derived transportation fuels.

Indirect coal liquefaction fuels derived from the Fischer-Tropsch process, in particular, contain substantially no sulfur and also exhibit lower particulate and carbon monoxide emissions. These fuels also contribute less to the formation of nitrogen oxides than petroleum derived fuels and they are readily biodegradable.

The production of coal-to-liquids fuels is also environmentally responsible. Because coal liquefaction processes remove contaminants from coal prior to combustion, process emissions from coal-to-liquids plants are much lower than traditional pulverized coal power plants.

Both direct and indirect coal liquefaction plants generate carbon dioxide in highly concentrated form allowing carbon capture and storage. Coal-to-liquids plants with carbon dioxide capture and storage can produce fuels with life cycle greenhouse gas emission profiles that are as good as or better than that of petroleum-derived products.

A life cycle greenhouse gas emissions inventory for indirect coal liquefaction diesel was prepared for the U.S. Department of Energy National Energy Laboratory (NETL) in June 2001. This study compared the emissions for indirect coal liquefaction (with and without carbon capture and storage) diesel with conventional petroleum diesel delivered to Chicago, IL. Some of the results from that study are summarized in the following table:

Feedstock	Grams of CO2-equivalent Emissions per Mile in a Sport Utility Vehicle				
	Extraction/ Production	Conversion/ Refining	Transportation/ Distribution	End Use Combustion	Total Fuel Chain
IL#6 Coal (ICL without CCS)	26	543	1	368	939
IL#6 Coal (ICL with CCS)	26	94	1	368	490
WY Sweet Crude Oil	23	74	8	363	468
Arab Light Crude Oil	35	81	26	367	509
Alberta Syncrude	32	104	10	370	516

Life cycle greenhouse gas emission inventories have not been completed on direct and hybrid coal liquefaction technologies. However, based on the fact that these technologies have lower plant CO_2 emissions than indirect coal liquefaction and the CO_2 is in concentrated form, it can be assumed that direct and hybrid technologies will have lower life cycle GHG emissions than conventional petroleum diesel.

Gasification technologies like those that would be used in coal-to-liquids plants have already demonstrated the ability to capture and store carbon dioxide on a large scale. For example, the Dakota Gasification facility in North Dakota captures CO_2 from the gasification process and transports it by pipeline to western Canadian oil fields where it is productively used for enhanced oil recovery.

There is also growing interest in utilizing coal and biomass (agricultural and forestry byproducts) together to further reduce net carbon dioxide emissions. This is achieved because biomass is considered a renewable resource and a zero net carbon dioxide emitter. The co-processing of coal and biomass would allow a much greater scale of liquid fuel production than an exclusive reliance on biofuels.

The co-processing of coal and biomass in commercial gasification plants is being done in Europe in the range of 80 to 90 percent coal and 10 to 20 percent biomass. It is speculated that up to 30 percent of the feed mix could be in the form of biomass; however there are economic and logistic issues to consider. Biomass is a bulky material with low density, high water content and is expensive to transport and preprocess for gasification. In addition, it tends to be seasonal and widely dispersed.

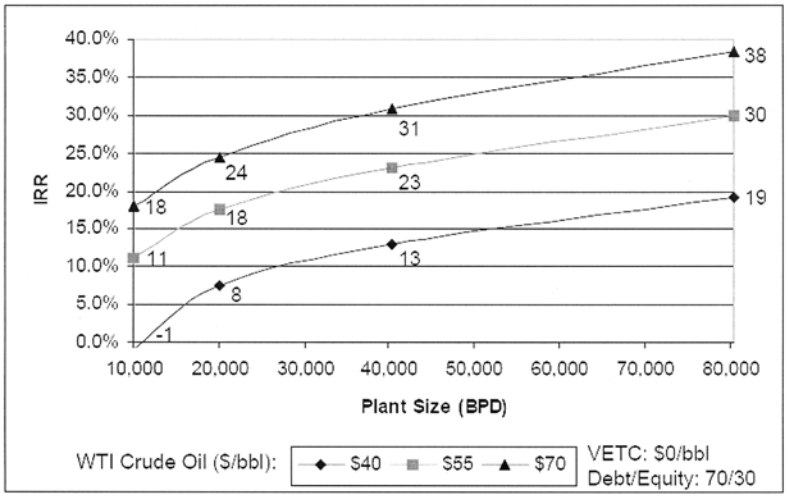
Coal-to-Liquids Economics Profile

Coal-to-liquids projects are capital intensive. Direct coal liquefaction is slightly less capital intensive than indirect coal liquefaction ($50,000–$60,000/bpd versus $60,000–$80,000/bpd). Escalating capital costs related to raw materials prices and equipment availability make small coal-to-liquids projects less economic and may force some developers to look at larger capacity projects on the order of 30,000 to 80,000 barrels per day to take advantage of economies of scale.

High capital costs ($2.5 billion to $6 billion per project) and large project size (30,000 to 80,000 barrels per day) will dictate where and how viable coal-to-liquids projects can be built. Multiple partners will likely be required to spread the risks and costs. These partners may include coal suppliers, technology providers, product users, operators, or private equity providers.

Large, low-cost coal reserves (from 500 million tons to over one billion tons) will be needed; preferably dedicated to the project. Coal-to-liquids plants can be adapted to handle any kind of coal through proper selection of the coal gasification technology.

The following graph indicates the impact of plant size on project economics. Large CTL plants (30,000 to 80,000 barrels per day) can compete with petroleum-derived products when crude oil prices exceed $35 to $45 per barrel, not including costs related to carbon capture and storage. In this case the debt to equity ratio was assumed to be 70:30 and did not include any government incentives on product sales. This graph is only for discussion purposes. Economic analysis should be based on site specific conditions for each project.



Coal-to-Liquids Commercialization Challenges

Estimates of the potential for coal-to-liquids vary widely. The Southern States Energy Board that posits the possibility of coal-to-liquids production exceeding five million barrels per day. The National Coal Council puts forth the vision of 2.6 million barrels per day by the year 2030. The Energy Information Administration reference case forecast projects coal-to-liquids production at about 800,000 barrels per day by 2030. This forecast assumes real oil prices increase 1.6 percent per annum over the forecast period. If real prices rise 3.6 percent per annum, EIA projects coal-to-liquids production to more than double to over 1.6 million barrels per day.

Although larger scale coal-to-liquids projects appear to be economically viable in today's oil price environment, there are still significant hurdles to get the first projects built. There are no coal-to-liquids plants operating in the U.S. that would serve as commercially proven models. Until that happens, financial institutions will be reluctant to fund multi-billion dollar projects without significant technology and market performance guarantees. This includes some assurance that plants will not be rendered uneconomic by oil producing nations or cartels that may seek to artificially reduce oil prices just long enough to prevent the formation of this competitive new industry.

Other nations are moving forward more aggressively to deploy coal-to-liquids technologies. In China, for instance, the government has already committed more than $30 billion to commercialization of coal gasification and liquefaction technologies and construction of the first plants has begun.

In the United States, Headwaters is one of several companies that are pursuing development of coal-to-liquids projects using private sector financing. As an example, one of the projects we are pursuing in the United States is the American Lignite Energy project located in North Dakota. American Lignite Energy features ample coal reserves, highly qualified development partners, and substantial existing infrastructure to support the facility. The State of North Dakota has been exceptionally supportive and has already committed $10 million of matching funds for front end engineering and design activities. But the project's viability is by no means certain. The task of raising upwards of $2 billion to build one of the first American coal-to-liquids refineries is daunting—especially for smaller companies like ours.

Headwaters certainly does not advocate abandoning America's open and efficient financial markets for a more centralized system like China's. But the United States should recognize that just because a technology is no longer a research project does not mean that the free market is ready to fully embrace it.

As long as oil prices remain high or climb higher, market forces will lead to the development of a coal-to-liquids infrastructure in the United States. But that development will come slowly and in measured steps. If for energy security reasons, the United States would like to speed development of a capability for making transpor-

tation fuels from our most abundant domestic energy resource, then incentives for the first coal-to-liquids project are appropriate.

Coal-to-Liquids Potential Commercialization Incentives

Incentives for commercializing coal-to-liquids technologies in the United States should be constructed to address the market risks that make financing of the first several plants difficult. For example, one widely discussed approach would establish an "oil price collar" to guide the government's investment. If oil prices were to drop below a specified level, the United States would make payments to coal-to-liquids projects participating in the program to ensure their viability. Alternatively, if oil prices rose above a higher specified level, the participating projects would pay back into the program. Properly constructed, such a program could have a meaningful effect on addressing the market risk associated with fluctuating oil prices.

The Coal-to-Liquids Coalition has also identified five specific actions the Federal Government could take to help overcome deployment barriers:

1. Provide funding, through non-recourse loans or grants, for Front End Engineering and Design (FEED) activities. These activities are necessary to define projects sufficiently to seek project financing in the private sector. FEED for a billion dollar project can cost upwards of $50 million.
2. Provide markets for the fuel produced by the first coal-to-liquids plants. Federal agencies like the Department of Defense are major consumers of liquid fuels. By agreeing to purchase coal derived fuels at market value, but not lower than a prescribed minimum price, the government can remove the risk of reductions in oil prices that could stop development of this industry.
3. Extend excise tax credit treatment for coal derived fuels. The recent SAFETEA–LU Bill extended to coal-derived fuels the approximately 50 cents per gallon excise tax credit that was originally created as an incentive for ethanol production. But the provision as now enacted will expire before any coal-to-liquids facilities could be placed in service.
4. Appropriate funds for loan guarantees authorized in the *Energy Policy Act of 2005* and ensure that those funds are made available to coal-to-liquids projects.
5. Ensure that industrial gasification tax credits authorized in the *Energy Policy Act of 2005* are also extended to coal-to-liquids projects.

Combined with support from states and local communities anxious to see development of coal resources, these actions would help private industry bridge the deployment gap and establish a coal-to-liquids capability more quickly for our nation.

Areas Needing Additional Research and Development

Research support is needed to continue to improve the efficiency and environmental performance of coal-to-liquids technologies with the goal of making this resource even cleaner.

Headwaters has for a period of over 25 years collaborated with DOE's National Energy Technology Laboratory (NETL) on a number of research and development activities related to the direct and indirect conversion of coal to transportation fuels and chemicals.

Most recently, we have benefited from a number of economic and technical reports and analyses on coal conversion processes that have been both created and made public by NETL. Particularly pertinent to today's discussion is a recently completed study for the Air Force, showing how coal biomass to liquids (CBTL) processes can be economically and environmentally competitive, not only in today's marketplace, but also in the future when the control of greenhouse gases becomes a national mandate.

Specific areas where continued research and development support would be beneficial include:

- Utilization of biomass as a strategy for reducing greenhouse gas emissions.
- Improving life cycle assessment tools for determining greenhouse gas emissions profiles for coal-to-liquids facilities when compared to other fossil fuel energy sources.
- Expanding methods of carbon capture and storage beyond currently available opportunities in the area of enhanced oil recovery.

Coal-to-Liquids Advantages

The advantages to developing a coal-to-liquids capability in the United States are numerous. Some of the dollars we now send overseas to buy oil would be kept at

home to develop American jobs utilizing American energy resources. We would expand and diversify our liquid fuels production and refining capacity using technologies that are already proven. We would produce clean-burning fuels that can be distributed through our existing pipelines and service stations to fuel our existing vehicles with no modifications to their engines. We would take a real and immediate step toward greater energy security.

Thank you for the invitation to testify and for your interest in this important topic. I would be happy to answer any questions.

Chairman LAMPSON. Dr. Bartis.

STATEMENT OF DR. JAMES T. BARTIS, SENIOR POLICY RESEARCHER, RAND CORPORATION

Dr. BARTIS. Thank you for inviting me to testify.

The United States oil consumers are currently paying about a half trillion dollars per year for crude oil, and most of that amount ends up being paid for by households, either directly or in higher prices for products and services. The bill averages to almost $5,000 per household per year. More over, the large amount of wealth transferred—on a global basis—from oil consumers to oil producers raises serious national security concerns because some, although certainly not all, of this revenue is being spent contrary to our foreign policy interests.

But no less pressing is the importance of addressing the threat of global climate change. For example, without measures to address carbon dioxide emissions, the use of coal-derived liquids to displace petroleum fuels for transportation will more than double greenhouse gas emissions. And this is clearly not acceptable.

The emphasis of our research at RAND on unconventional fuels has concentrated on what is known as the Fischer-Tropsch coal-to-liquids method. We find this option to be the only unconventional fuel option that is commercially ready today and capable of eventually displacing millions of barrels per day of imported petroleum.

Producing large amounts of unconventional fuels, including coal-derived liquid fuels, and moving towards greater energy efficiency will cause world oil prices to decrease. Our research shows that under reasonable assumptions this price reduction effort could be very large and would likely result in large benefits to U.S. consumers and large decreases in OPEC's revenues.

We have also examined whether a large domestic coal-to-liquids industry can be developed consistent with the need to manage carbon dioxide emissions.

If we are willing to accept emission levels that are similar to those associated with conventional petroleum, the answer is definitely yes. One technical approach for achieving parity with petroleum is the capture and sequestration of the carbon dioxide generated at the plant site.

A second approach involves using a combination of coal and biomass as we just heard. Fortunately, the second approach is very low risk, although not quite ready for commercial production.

Now, given the large demand on OPEC oil that we anticipate will persist over the next 50 years, this is a very good answer. We can at least address a major economic and national security problem while not worsening environmental impacts, at least on the global scale.

If, however, we demand a significant reduction in the emission levels as compared to conventional petroleum, the answer is a qualified yes. The only way we know of reaching this level of carbon dioxide control when making coal-derived fuels is to use a combination of coal and biomass as the feed for the plant and to capture and sequester most of the carbon dioxide generated at the plant site. The reason I give a qualified yes is that there does remain considerable uncertainty regarding the viability of sequestering carbon dioxide in geological formations.

Against this background of benefits and challenges, federal R&D has an important role to play. Foremost in priority are multiple large-scale demonstrations of carbon sequestration. Our analysis shows that the limiting factor in the growth of a domestic coal-to-liquids industry will be the time required to determine whether and how hundreds of millions of tons of carbon dioxide can be annually sequestered.

The remainder of my recommendations follow from what we at RAND describe as the middle path to coal-to-liquids development, namely a path that focuses on reducing uncertainties, fostering early, but very limited, commercial experience; and reducing greenhouse gas emissions.

First, Congress should consider providing federal cost sharing for a few site-specific front-end engineering designs of commercial plants to convert coal-to-liquid fuels so that government and private investors have better information on production costs. At RAND we have learned that when it comes to cost estimates it is often the case that the less you know the more attractive the costs.

Second, Congress should consider establishing a flexible incentive program capable of promoting the construction and operation of a few early coal-to-liquid plants by our country's top technology firms. The early plants could also serve as demonstration platforms for carbon capture and sequestration and the combined use of biomass and coal.

Third, the current energy R&D program on transportation fuels in the Department of Energy is too narrowly focused on hydrogen and ethanol from cellulosic materials. This program needs to expand to provide adequate support to gasification of biomass or a combination of coal and biomass.

The most pressing near-term research need centers on developing a fuel handling and gasification system capable of accepting both biomass and coal.

Finally, I recommend consideration of a number of important high-risk, high-payoff research opportunities that are not being addressed in the current federal program because they require a longer timeframe for execution, and these opportunities are covered in my written testimony.

This concludes my remarks. Thank you.

[The prepared statement of Dr. Bartis follows:]

PREPARED STATEMENT OF JAMES T. BARTIS[1]

Research and Development Issues for Producing Liquid Fuels From Coal

Mr. Chairman and distinguished Members: Thank you for inviting me to speak on technical issues associated with the potential use of our nation's coal resources to produce liquid fuels. I am a senior policy researcher at the RAND Corporation with more than 25 years of experience in analyzing and assessing energy technology and policy issues. At RAND, I am actively involved in research directed at understanding the costs and benefits associated with alternative approaches for promoting the use of coal and other domestically abundant resources, such as oil shale and biomass, to lessen our nation's dependence on imported petroleum. Various aspects of this work are sponsored and funded by the National Energy Technology Laboratory (NETL) of the U.S. Department of Energy, the U.S. Air Force, the Federal Aviation Administration, and the National Commission on Energy Policy.

Today, I will discuss the key problems and policy issues associated with developing a domestic coal-to-liquids industry and the approaches Congress can take to address these issues. My main conclusions are as follows. First, successfully developing a coal-to-liquids industry in the United States would bring significant economic and national security benefits by reducing energy costs and wealth transfers to oil-exporting nations. Second, the production of petroleum substitutes from coal may cause a significant increase in carbon dioxide emissions; however, relatively low-risk research opportunities exist that, if successful, could lower carbon dioxide emissions to levels well below those associated with producing and using conventional petroleum. Third, without federal assistance, sufficient private-sector investment in coal-to-liquids production plants is unlikely to occur because of uncertainties about the future of world oil prices, the costs and performance of initial commercial plants, and the viability of carbon management options. Finally, a federal program directed at reducing these uncertainties; obtaining early, but limited, commercial experience; and supporting research appears to offer the greatest strategic benefits, given both economic and national security benefits and the uncertainties associated with economic viability and environmental performance, most notably the control of greenhouse gas emissions.

Some of the topics I will be discussing today are supported by research that RAND has only recently completed; consequently, the results have not yet undergone the thorough internal and peer reviews that typify RAND research reports. Out of respect for this committee and the sponsors of this research, and in compliance with RAND's core values, I will present only findings in which RAND and I have full confidence at this time.

Technical Readiness and Production Potential

As part of RAND's examination of coal-to-liquids fuels development, we have reviewed the technical, economic, and environmental viability and production potential of a range of options for producing liquid fuels from domestic resources. If we focus on unconventional fuel technologies that are now ready for large-scale, commercial production and that can displace at least a million barrels per day of imported oil, we find only two candidates: grain-derived ethanol and Fischer-Tropsch (F–T) coal-to-liquids. Moreover, only the F–T coal-to-liquids candidate produces a fuel that is suitable for use in heavy-duty trucks, railroad engines, commercial aircraft, or military vehicles and weapon systems.

If we expand our time horizon to consider technologies that might be ready for use in initial commercial plants within the next five years, only one or two new technologies become available: the in-situ oil shale approaches being pursued by several firms and the F–T approaches for converting biomass or a combination of coal and biomass to liquid fuels. We have also looked carefully at the development prospects for technologies that are intended to produce alcohol fuels from sources other than food crops, generally referred to as *cellulosic materials.* Our finding is that, while this is an important area for research and development, the technology base

[1] The opinions and conclusions expressed in this testimony are the author's alone and should not be interpreted as representing those of RAND or any of the sponsors of its research. This product is part of the RAND Corporation testimony series. RAND testimonies record testimony presented by RAND associates to federal, State, or local legislative committees; government-appointed commissions and panels; and private review and oversight bodies. The RAND Corporation is a nonprofit research organization providing objective analysis and effective solutions that address the challenges facing the public and private sectors around the world. RAND's publications do not necessarily reflect the opinions of its research clients and sponsors.

is not yet sufficiently developed to support an assessment that alcohol production from cellulosic materials will be competitive with F–T biomass-to-liquid fuels within the next 10 years, if ever.

The Strategic Benefits of Coal-to-Liquids Production

Our research is also addressing the strategic benefits of having in place a mature coal-to-liquid fuels industry producing several million barrels of oil per day. If coal-derived liquids were added to the world oil market, such additional liquid fuel supplies would cause world oil prices to be lower than they would be if these additional supplies were not produced. This effect occurs regardless of what fuel is being considered. It holds for coal-derived liquids and for oil shale, heavy oils, tar sands, and biomass-derived liquids, as well as, for that matter, additional supplies of conventional petroleum. The price-reduction effect also occurs when oil demand is reduced through fiscal measures, such as taxes on oil, or through the introduction of advanced technologies that use less petroleum, such as higher efficiency vehicles. Moreover, this reduction in world oil prices is independent of where such additional production or energy conservation occurs, as long as the additional production is outside of OPEC and OPEC-cooperating nations.

In a 2005 analysis of the strategic benefits of oil shale development, RAND estimated that three million barrels per day of additional liquid-fuel production would yield a world oil price drop of between three and five percent.[2] Our ongoing research supports that estimated range and shows that the price drop increases in proportion to production increases. For instance, an increase of six million barrels per day would likely yield a world oil price drop of between six and 10 percent. This more recent research also shows that even larger price reductions may occur in situations in which oil markets are particularly tight or in which OPEC is unable to enforce a profit-optimizing response among its members.

This anticipated reduction in world oil prices yields important economic benefits. In particular, U.S. consumers would pay tens of billions of dollars less for oil or, under some future situations, hundreds of billions of dollars less for oil per year. On a per-household basis, we estimate that the average annual benefit could range from a few hundred to a few thousand dollars.

Further, this anticipated reduction in world oil prices also yields a major national security benefit. At present, OPEC revenues from oil exports are about $700 billion per year. Projections of future petroleum supply and demand published by the U.S. Department of Energy indicate that, unless measures are taken to reduce the prices of, and demand for, OPEC petroleum, such revenues will grow considerably. These high revenues raise serious national security concerns, because some OPEC member nations are governed by regimes that are not supportive of U.S. foreign policy objectives. Income from petroleum exports has been used by unfriendly nations, such as Iran and Iraq under Saddam Hussein, to support weapon purchases or to develop their own industrial base for munitions manufacture. Also, the higher prices rise, the greater the chances that oil-importing countries will pursue special relationships with oil exporters and defer joining the United States in multilateral diplomatic efforts.

Our research shows that developing an unconventional fuels industry that displaces millions of barrels of petroleum per day will cause a significant decrease in OPEC revenues from oil exports. This decrease results from a combination of lower prices and a lower demand for OPEC production. The size of this reduction in OPEC revenues is determined by the volume of unconventional fuels produced and future market conditions, but our ongoing research indicates that expectations of annual reductions of hundreds of billions of dollars are not unreasonable. The significant reduction in wealth transfers to OPEC and the geopolitical consequences of reduced demand for OPEC oil represent the major national security benefits associated with the development of an unconventional liquid fuels production industry. Note that these revenue reductions would affect all petroleum exporters, both friends and foes.

These strategic benefits derive from the existence of the OPEC cartel. The favorable benefits of reduced oil prices accrue to consumers and the Nation as a whole; however, the private firms that would invest in coal-to-liquids development do not capture those benefits.

The Direct Benefits of Coal-to-Liquids Production

Beyond the strategic benefits for the Nation associated with coal-to-liquids production are certain direct benefits. If coal-derived liquid fuels can be produced at prices well below world oil prices, then the private firms that invest in coal-derived liquid

[2] *Oil Shale Development in the United States: Prospects and Policy Issues,* Bartis et al., Santa Monica, Calif.: RAND Corporation, MG–414–NETL, 2005.

fuels development could garner economic profits above and beyond what is considered a normal return on their investments. Through taxes on these profits and, in some cases, lease and royalty payments, we estimate that roughly 35 percent of these economic profits could go to Federal, State, and local governments and, thereby, broadly benefit the public.

An auxiliary benefit of coal-to-liquids development derives from the broad regional dispersion of the U.S. coal resource base and the fact that coal-to-liquids plants are able to produce finished motor fuels that are ready for retail distribution. As such, developing a coal-to-liquids industry should increase the resiliency of the overall petroleum supply chain.

The remaining benefits of developing a coal-to-liquids production industry are local or regional, as opposed to national. In particular, coal-to-liquids industrial development offers significant opportunities for economic development and would increase employment in coal-rich states.

Greenhouse Gas Emissions

While the strategic benefits of the development of a domestic coal-to-liquids industry are compelling, no less pressing is the importance of addressing the threat of global climate change. Specifically, without measures to address carbon dioxide emissions, the use of coal-derived liquids to displace petroleum fuels for transportation will roughly double greenhouse gas emissions.

This finding is relevant to the total fuel life cycle, i.e., well-to-wheels or coal mine-to-wheels. This increase in greenhouse gas emissions is primarily attributable to the large amount of carbon dioxide emissions that come from an F–T coal-to-liquids production plant relative to a conventional oil refinery. In fact, looking solely at the combustion of F–T-derived fuel as opposed to its production, our analyses show that combustion of an F–T, coal-derived fuel would produce somewhat, although not significantly, *lower* greenhouse gas emissions than would the combustion of a gasoline or diesel motor fuel prepared by refining petroleum.

In our judgment, the high greenhouse gas emissions of F–T coal-to-liquids plants that do not manage such emissions preclude their widespread use as a means of displacing imported petroleum. We now turn to some options for managing greenhouse gas emissions.

Options for Managing Greenhouse Gas Emissions

For managing greenhouse gas emissions for F–T coal-to-liquids plants, we have examined three options: (1) carbon capture and sequestration, (2) carbon dioxide capture and use in enhanced oil recovery, and (3) gasification of both coal and biomass followed by F–T synthesis of liquid fuels. We discuss each below in turn.

Carbon Capture and Sequestration: By carbon capture and sequestration, I refer to technical approaches being developed in the United States, primarily through funding from the U.S. Department of Energy, and abroad that are designed to capture carbon dioxide produced in coal-fired power plants and to sequester that carbon dioxide in various types of geological formations, such as deep saline aquifers. This same approach can be used to capture and sequester carbon dioxide emissions from F–T coal-to-liquids plants and from F–T plants operating on biomass or a combination of coal and biomass. When applied to F–T coal-to-liquids plants, carbon capture and sequestration should cause mine-to-wheels greenhouse gas emissions to drop to levels comparable to the well-to-wheels emissions associated with conventional, petroleum-derived motor fuels. Most importantly, our research indicates that any incentive adequate to promote carbon capture at coal-fired power plants should be even more effective in promoting carbon capture at F–T plants producing liquid fuels.

The U.S. Department of Energy program on carbon capture and sequestration has made considerable technical progress. However, considering the continued and growing importance of coal for both power and liquids production and the potential adverse impacts of greenhouse gas emissions, we believe that current funding levels are not adequate. While we are optimistic that carbon capture and geologic sequestration can be successfully developed as a viable approach for carbon management, we also recognize that successful development constitutes a major technical challenge and that the road to success requires multiple, large-scale demonstrations that go well beyond the current U.S. Department of Energy plans and budget for the efforts that are now under way.

Carbon Capture and Enhanced Oil Recovery: In coal-to-liquids plants, about 0.8 tons of carbon dioxide are produced along with each barrel of liquid fuel. For coal-to-liquids plants located near currently producing oil fields, this carbon dioxide can be used to drive additional oil recovery. We anticipate that each ton of carbon

dioxide applied to enhanced oil recovery will cause the additional production of two to three barrels of oil, although this ratio depends highly on reservoir properties and oil prices. Based on recent studies sponsored by the U.S. Department of Energy, opportunities for enhanced oil recovery provide carbon management options for at least half a million barrels per year of coal-to-liquids production capacity. A favorable collateral consequence of this approach to carbon management is that half a million barrels per day of coal-to-liquids production will promote additional domestic petroleum production of roughly one million barrels per day.

The use of pressurized carbon dioxide for enhanced oil recovery is a well-established practice in the petroleum industry. Technology for capturing carbon dioxide at a coal-to-liquids plant is also well established, although further R&D may yield cost reductions. There are no technical risks, but questions do remain about methods to optimize the fraction of carbon dioxide that would be permanently sequestered.

Combined Gasification of Coal and Biomass: Non-food-crop biomass resources suitable as feedstocks for F–T biomass-to-liquid production plants include mixed prairie grasses, switchgrass, corn stover and other crop residues, forest residues, and crops that might be grown on dedicated energy plantations. When such biomass resources are used to produce liquids through the F–T method, our research shows that greenhouse gas emissions should be well below those associated with the use of conventional petroleum fuels. Moreover, when a combination of coal and biomass is used, for example, a 40–60 mix, we estimate that net carbon dioxide emissions will be comparable to or, likelier, lower than well-to-wheels emissions of conventional, petroleum-derived motor fuels. Finally, we have examined liquid fuel production concepts in which carbon capture and sequestration is combined with the combined gasification of coal and biomass. Our preliminary estimate is that a 50–50 coal-biomass mix combined with carbon capture and sequestration should yield negative carbon dioxide emissions. Negative emissions imply that the net result of producing and using the fuel would be the removal of carbon dioxide from the atmosphere.

One perspective on the combined gasification of coal and biomass is that biomass *enables* F–T coal-to-liquids production, in that the combined feedstock approach provides an immediate pathway to unconventional liquids with no net increase in greenhouse gas emissions, and an ultimate vision, with carbon capture and sequestration, of zero net emissions. Another perspective is that coal *enables* F–T biomass-to-liquids production, in that the combined approach reduces overall production costs by reducing fuel delivery costs, allowing larger plants that take advantage of economies of scale, and smoothing over the inevitable fluctuations in biomass availability associated with annual and multi-year fluctuations in weather patterns, especially rainfall.

Prospects for a Commercial Coal-to-Liquids Industry

The prospects for a commercial coal-to-liquids industry in the United States remain unclear. Three major impediments block the way forward:

1. Uncertainty about the costs and performance of coal-to-liquids plants;
2. Uncertainty about the future course of world oil prices; and
3. Uncertainty about whether and how greenhouse gas emissions, especially carbon dioxide emissions, might be controlled in the United States.

As part of our ongoing work, RAND researchers have met with firms that are promoting coal-to-liquids development or that clearly have the management, financial, and technical capabilities to play a leading role in developing of a commercial industry. Our findings are that these three uncertainties are impeding and will continue to impede private-sector investment in a coal-to-liquids industry unless the government provides fairly significant financial incentives, especially incentives that mitigate the risks of a fall in world oil prices.

But just as these three uncertainties are impeding private-sector investment, they should also deter an immediate national commitment to establish rapidly a multi-million-barrel-per-day coal-to-liquids industry. However, the traditional hands-off or "research-only" approach is not commensurate with continuing adverse economic, national security, and global environmental consequences of relying on imported petroleum. For this reason, Congress should consider a middle path to developing a coal-to-liquids industry that focuses on reducing uncertainties and fostering early operating experience by promoting the construction and operation of a limited number of commercial-scale plants. We consider this approach an "insurance strategy," in that it is an affordable approach that significantly improves the national capability to build a domestic unconventional-fuels industry as government and industry

learn more about the future course of world oil prices and as the policy and technical mechanisms for carbon management become clearer.

Designing, building, and gaining early operating experience from a few coal-to-liquids plants would reduce the cost and performance uncertainties that currently impede private-sector investments. At present, the knowledge base for coal-to-liquids plant construction costs and environmental performance is very limited. Our current best estimate is that coal-to-liquids production from large, first-of-a-kind commercial plants is competitive when crude oil prices average in the range of $50 to $60 per barrel. However, this estimate is based on highly conceptual engineering design analyses that are intended only to provide rough estimates of costs. At RAND, we have learned that, when it comes to cost estimates, typically the less you know, the more attractive the costs. Details are important, and they are not yet available. For this reason, we believe that it is essential that the Department of Energy and Congress have access to the more reliable costing that is generally associated with the completion of a more comprehensive design effort, generally known as a "front-end engineering design."

Early operating experience would promote post-production learning, leading to future plants with lower costs and improved performance. Post-production cost improvement—sometimes called the learning curve—plays a crucial role in the chemical process industry, and we anticipate that this effect will eventually result in a major reduction of the costs of coal-derived liquid fuels. Most important, by reducing cost and performance uncertainties and production costs, a small number of early plants could form the basis for a rapid expansion by the private sector of a more economically competitive coal-to-liquids industry, depending on future developments in world oil markets.

Options for Federal Action

The Federal Government could take several productive measures to address the three major uncertainties we have noted—production risks, market risks, and global warming—so that industry can move forward with a limited commercial production program consistent with an insurance strategy. A key step, as noted, is reducing uncertainties about plant costs and performance by encouraging the design, construction, and operation of a few coal-to-liquids plants. An engineering design adequate to obtain a confident estimate of costs, to establish environmental performance, and to support federal, State, and local permitting requirements will cost roughly $30 million. The Federal Government should consider cost-sharing options that would promote the development of a few site-specific designs. The information from such efforts would also provide Congress with a much stronger basis for designing broader measures to promote unconventional-fuel development.

We have analyzed alternative incentive packages for promoting early commercial operating experience. In this analysis of incentives, we have examined not only the extent to which the incentive motivates private-sector investment but also the potential impact on federal expenditures over a broad range of potential future outcomes. At this time, we are able to report that more attractive incentive packages generally involve a combination of the following three mechanisms: (1) a reduction in front-end investment costs, such as what would be offered by an investment tax credit; (2) a reduction in downside risks by a floor price guarantee; and (3) a sharing of upside benefits such as what would be offered by a profit-sharing agreement between the government and producers when oil prices are high enough to justify such sharing.

We also find that federal loan guarantees can have powerful effects, mainly because they allow the share of debt supporting the project to increase, since the government is assuming the risk of project default. For this very reason, we caution against the use of federal loan guarantees unless Congress is confident that the Federal Government is able to put in place a technical and financial project monitoring and control system capable of protecting the federal purse.

R&D Opportunities

A great benefit of the F–T approach to liquid fuel development is that we know it works. F–T fuels are being produced today using both coal and natural gas in South Africa and using natural gas in Malaysia and Qatar. F–T fuels or blends of F–T and conventional petroleum products are in commercial use. Their suitability for use in vehicles and commercial aviation has been established. The R&D challenge for coal-to-liquids development is not how to use but rather how to produce these fuels in a manner that is consistent with our national environmental objectives.

If the Federal Government is prepared to promote early production experience, then expanded federal R&D efforts are needed. Most important, consideration

should be given to accelerating the development and testing (including large-scale testing) of methods for the long-term sequestration of carbon dioxide. This could involve using one or more of the early coal-to-liquids production plants as a source of carbon dioxide for the testing of sequestration options.

At present, the Federal Government is supporting research on coal gasification and associated synthesis gas cleaning and treatment processes. All of this federally funded research is directed at nearer-term, lower-risk concepts for advanced power generation and the production of hydrogen, but much of it is also directly applicable to F–T coal-to-liquids production.

Missing from the federal R&D portfolio are near-term efforts to establish the commercial viability of a few techniques for the combined use of coal and biomass. Such a combination offers significant cost and environmental payoffs. The most pressing near-term research need centers on developing an integrated gasification system capable of handling both biomass and coal. The problem is to devise a system that grinds, pressurizes, and feeds a stream of biomass or a combination of biomass and coal into the gasifier with high reliability and efficiency and without damaging the gasifier. This is a fairly minor technical challenge. It is an engineering problem focusing on performance and reliability, not a science problem. To establish the design basis for such a system requires the design, construction, and operation of one or a few test rigs. These test rigs need to be fairly large so that they are handling flows close to what would be the case in a commercial plant. This is because solids are involved, and it is very difficult to predict performance and reliability of solids-handling and processing systems when the size or throughput of the system undergoes a large increase. Such large-scale testing could also be conducted during the design and construction of a full-scale plant for coal-to-liquids production, with the understanding that, if this were successfully demonstrated, the plant would convert to accept a mixture of coal and biomass.

In my judgment, the current federal portfolio on gasification systems does not give adequate support to mid- and long-term R&D directed at high-risk, high-payoff opportunities for cost reduction and improved efficiency and environmental performance. Especially fruitful areas for R&D are oxygen production at reduced energy consumption, improved gas-gas separation technology, higher-temperature gas-purification systems, and reduced or eliminated oxygen demand during gasification. I also suggest research directed at advanced F–T process concepts that allow efficient liquid-fuels production at small scales, i.e., at a few thousand barrels per day, not tens of thousands. Very large F–T coal-to-liquids plants may be suitable for Wyoming and Montana, but east of the Mississippi, much smaller plants may be more appropriate.

In promoting the production of alcohol fuels from cellulosic feedstocks, the Federal Government is making major R&D investments. In our judgment, the appropriate approach to balance this fuels-production portfolio is not to lower the investment in cellulosic conversion, but rather to significantly increase the investment in F–T approaches, including coal, biomass, and combined coal and biomass gasification.

The long- and mid-term research efforts that I have described would significantly enhance the learning and cost-reduction potential associated with early production experience. As a collateral benefit of this public investment, such longer-term research efforts would also support the training of specialized scientific and engineering talent required for long-term progress.

In closing, I commend the Committee for addressing the important and intertwined topics of reducing demand for crude oil and reducing greenhouse gas emissions. The United States has before it many opportunities—including coal and oil shale, renewable sources, improved energy efficiency, and fiscal and regulatory actions—that can promote greater energy security. Coal-to-liquids and, more generally, F–T gasification processes can be important parts of the portfolio as the Nation responds to the realities of world energy markets, the presence of growing energy demand, and the need to protect the environment.

BIOGRAPHY FOR JAMES T. BARTIS

James T. Bartis, Ph.D. is a senior policy researcher with more than 25 years of experience in policy analyses and technical assessments in energy and national security. He is currently finishing up a study of the policy issues associated with the development of a coal-to-liquids industry in the United States. Recent energy research topics include oil shale development prospects, Qatar's natural gas-to-diesel plants, Japan's energy policies, planning methods for long-range energy R&D, critical mining technologies, fuel cell development options, and national response options during international energy emergencies.

Jim has been working with the RAND Corporation since 1997. He is located at RAND's Arlington, Virginia office. Prior to joining RAND, he worked as a Vice President and Division Director for Science Applications International Corporation, and earlier as Vice President of Eos Technologies.

From 1978 through 1982, he was a member of the U.S. Department of Energy, serving in the in the Office of Energy Research (technical policy analyst), the Office of Fossil Energy (Director, Office of Plans and Technology Assessment), and Office of Policy and Evaluation (Director, Divisions of Fossil Energy and Environment). During the Bush and Clinton Administrations, he served on the Industry Sector Advisory Committee (U.S. Department of Commerce and U.S. Trade Representative) on Energy for Trade Policy Matters.

Jim is a graduate of Brown University and holds a Ph.D. granted by MIT.

Chairman LAMPSON. Thank you very much.

Mr. Hawkins.

STATEMENT OF DR. DAVID G. HAWKINS, DIRECTOR, CLIMATE CENTER, NATURAL RESOURCES DEFENSE COUNCIL

Dr. HAWKINS. Thank you, Mr. Chairman, Members of the Subcommittee. Thank you for inviting me to testify today.

As has already been noted by several Members and by the witnesses, we are facing as a nation, indeed as a planet, two large and growing threats; oil dependence and global warming. It is critical that we address these together in designing strategies for energy and environmental protection.

Now, the supporters of coal-to-liquids technology claim that the fuel can both reduce oil dependence and can have greenhouse gas emissions that are as good or better than the petroleum products that they replace. Well, those are claims, and this is the Science and Technology Committee, and good science requires that the claims be analyzed.

The problem is that these claims have not had the scrutiny that is required given the attention that Congress has been paying to this matter. Certainly, the objective analysis of the total life cycle impacts of this approach of coal-to-liquids to addressing these twin problems compared to other alternatives have not been presented to Congress, and they are certainly no basis for the mandates and incentives that have been fuel-specific that have been voted on in both bodies of Congress, fortunately neither has been enacted fortunately in our view.

Because to do so would be making a mistake, given the lack of analysis that has been provided about the merits of this approach compared to others. So let us take a look at a number of these issues in the time that I have.

First, as to greenhouse gas emissions, the most authoritative analysis by the Argonne National Labs indicates that without carbon capture, coal-to-liquids will produce more than twice the well-to-wheels greenhouse gas emissions of diesel fuel, and even with 85 percent capture of carbon from a coal-to-liquids plant, the resulting emissions will still be about 20 percent greater than conventional diesel fuel.

Now, let us compare this to alternative ways of using coal to back out oil, because there are alternative ways. One of them is with plug-in hybrid vehicles. We can have coal, turn it into electricity. If we do that in a modern plant that is equipped with carbon capture and storage, we can back out about twice as many barrels of oil per ton of coal as compared to the coal-to-liquids tech-

nology, and we can do it with one-tenth the greenhouse gas emissions. These are facts that haven't been presented to the Congress, and it ought to be evaluated before we move forward with what is likely to be a sub-optimal approach.

The problems that I want to turn to next are problems of scale. In order to make a difference on oil security, a coal-to-liquids industry has to be huge. In order to cut coal, oil consumption projected for 2025 by 10 percent, that requires something on the order of 470 million tons of additional coalmining in this country. That is a 43 percent increase in today's level of coalmining. Unfortunately, today's level of coalmining is associated with a lot of environmental damage. We need reform of our coalmining practices before we contemplate that magnitude of an increase in coal production.

The water use is another issue, and I believe that Dr. Boardman will address it, but water use for coal-to-liquids technology is large indeed, perhaps as high as 12 gallons for every gallon of fuel produced.

Then there is the impact on the coal market itself. Congressman Bartlett's opening statement notes that the reserve estimates for coal, while apparently large, are themselves uncertain. And if we increase coal production in order to back out oil through the liquid coal market, the impacts on recoverable reserves could be profound. In my testimony I point out that if we tried to back out just one-third of oil imports starting in 2030, that by 2050, 40 percent of today's estimated recoverable coal reserves would be gone, and by 2080, they would all be gone. If we tried to do more than one-third of oil imports, then the impacts would be that much greater.

There is also the impact of carbon capture and storage. This technology would add a large new demand for reservoir space, and as Dr. Bartis had noticed, has noticed, we already will have a challenge with deploying carbon capture technology for the electric power sector. So we need to think about that.

In conclusion, let me make a recommendation. Rather than mandate a fuel-specific approach or adopt incentives for a fuel-specific approach, we need a fuel-neutral approach. We should have incentives and performance standards that reward entrepreneurs who deliver alternatives to oil that do the best job at backing out oil and do the best job at cutting greenhouse gas emissions. And that is the approach that we recommend.

Thank you.

[The prepared statement of Dr. Hawkins follows:]

PREPARED STATEMENT OF DAVID G. HAWKINS

Thank you for the opportunity to testify today on the subject of producing liquid fuels from coal. My name is David Hawkins. I am Director of the Climate Center at the Natural Resources Defense Council (NRDC). NRDC is a national, nonprofit organization of scientists, lawyers and environmental specialists dedicated to protecting public health and the environment. Founded in 1970, NRDC has more than 1.2 million members and online activists nationwide, served from offices in New York, Washington, Los Angeles and San Francisco, Chicago and Beijing, China.

Today's energy use patterns are responsible for two growing problems that require action now to keep them from spiraling out of control—oil dependence and global warming. Both are serious but most important, both problems must be addressed together. Designing strategies that address only oil dependence and ignore global warming would be a huge and costly mistake.

Proposals to use coal to make liquid fuels for transportation need to be evaluated in the context of the compelling need to reduce global warming emissions starting now and proceeding continuously throughout this century. Because today's coal mining and use also continues to impose a heavy toll on America's land, water, and air, damaging human health and the environment, it is critical to examine the implications of a substantial liquid coal program on these values as well. The first role for federal research should be to identify through comprehensive studies the types of vehicles and fuels that hold the best promise of reducing both oil dependence and global warming pollution by the amounts required to preserve a climate that allows us and others to achieve our environmental, economic and security objectives.

Reducing oil dependence

NRDC fully agrees that reducing oil dependence should be a national priority and that new policies and programs are needed to avert the mounting problems associated with today's dependence and the much greater dependence that lies ahead if we do not act. A critical issue is the path we pursue in reducing oil dependence: a "green" path that helps us address the urgent problem of global warming and our need to reduce the impacts of energy use on the environment and human health; or a "brown" path that would increase global warming emissions as well as other health and environmental damage. In deciding what role coal might play as a source of transportation fuel NRDC believes we must first assess whether it is possible to use coal to make liquid fuels without exacerbating the problems of global warming, conventional air pollution and impacts of coal production and transportation.

If coal were to play a significant role in displacing oil, it is clear that the enterprise would be huge, so the health and environmental stakes are correspondingly huge. The coal company Peabody Energy and its industry allies are seeking government subsidies to create a coal to synfuels industry as large as 2.6 million barrels per day of liquid fuel from coal by 2025, about 10 percent of forecasted oil demand in that year. According to the industry, using coal to produce that much synfuel would require construction of 33 very large liquid coal plants, each plant consuming 14.4 million tons of coal per year to produce 80,000 barrels per day of liquid fuel. Each of these plants would cost $6.4 billion to build. Total additional coal production required for this program would be 475 million tons of coal annually-requiring an expansion of coal mining of 43 percent above today's level.[1]

In this testimony I will not attempt a thorough analysis of the impacts of a program of this scale. Rather, I will highlight the issues that should be addressed in a detailed assessment.

Global Warming Pollution

To avoid catastrophic global warming the U.S. and other nations will need to deploy energy resources that result in much lower releases of CO_2 than today's use of oil, gas and coal. To keep global temperatures from rising to levels not seen since before the dawn of human civilization, the best expert opinion is that global greenhouse gas emissions need to be cut in half from today's levels by 2050. To accommodate unavoidable increases in emissions from developing countries this will require industrialized countries, including the U.S., to cut emissions by about 80 percent from today's levels between now and 2050.

Achieving emissions reductions of this scale in the U.S. will require deep reductions in all sectors, especially in the power generation and transportation sectors, which together account for over two-thirds of U.S. carbon dioxide (CO_2) emissions. Achieving large reductions in transportation emissions will require action on three fronts: improved vehicles; lower carbon fuels; and smarter metropolitan area planning to reduce congestion and growth in vehicle miles. This is the frame we must have in mind in evaluating the viability of alternative fuels for the transportation sector. The fuel industry we build must be capable of producing fuels that contain substantially less fossil carbon than is in today's petroleum-based gasoline and diesel fuel. To help achieve the overall reductions we need by 2050 will require transportation fuels with 50–80 percent lower fossil carbon emission potential than today's fuels.

To assess the global warming implications of a large liquid coal program we need to examine the total life cycle or "well-to-wheel" emissions of this type of synfuel. Coal is a carbon-intensive fuel, containing double the amount of carbon per unit of

[1] The coal industry's program is set forth in a March 2006 National Coal Council report, *Coal: America's Energy Future.* The industry's full "Eight-Point Plan" calls for a total of 1.3 billion tons of additional coal production by 2025, proposing that coal be used to produce synthetic pipeline gas, additional coal-fired electricity, hydrogen, and fuel for ethanol plants. The entire program would more than double U.S. coal mining and consumption.

energy compared to natural gas and about 50 percent more than petroleum. When coal is converted to liquid fuels, two streams of CO_2 are produced: one at the liquid coal production plant and the second from the exhausts of the vehicles that burn the fuel. As I describe below, even if the CO_2 from the synfuel production plant is captured, there is no prospect that liquid fuel made with coal as the sole feedstock can achieve the significant reductions in fossil carbon content that we need to protect the climate.

Two authoritative recent studies conclude that even if liquid coal synfuels plants fully employ carbon capture and storage, full life cycle greenhouse gas emissions from using these fuels will be worse than conventional diesel fuel. There is a straightforward reason for this. Vehicle tailpipe CO_2 emissions from using liquid coal would be nearly identical to those from using conventional diesel fuel. Any CO_2 emissions released from the synfuels production facility have to be added to the tailpipe emissions. The residual emissions from a liquid coal plant employing CO_2 capture and geologic storage (CCS) are still somewhat higher than emissions from a petroleum refinery, hence life cycle emissions are higher.

EPA's April 2007 analysis of life cycle greenhouse gas emissions of different fuels was released in conjunction with publishing its final rule to implement the Renewable Fuels Standard enacted in the *Energy Policy Act of 2005.* EPA's analysis finds that without carbon capture life cycle greenhouse gas emissions from coal-to-liquid fuels would be more than twice as high as from conventional diesel fuel (118 percent higher). Assuming carbon capture and storage EPA finds that life cycle greenhouse gas emissions from coal-to-liquid fuels would be 3.7 percent higher than from conventional diesel fuel.[2]

In May 2007 Michael Wang of Argonne National Laboratory, the developer of the most widely used transportation fuels life cycle emissions model, presented the results of his more detailed analysis of liquid coal fuels to the Society of Automotive Engineers conference. The Argonne analysis shows that liquid coal fuels could have life cycle greenhouse gas emissions as much as 2.5 times those from conventional diesel fuel. Even assuming a high-efficiency liquid coal conversion process and 85 percent carbon capture and storage, Argonne finds that life cycle greenhouse gas emissions from liquid coal fuel would still be 19 percent higher than from conventional diesel fuel (Figure 1).[3]

[2] *http://www.epa.gov/otaq/renewablefuels/420f07035.htm*

[3] M. Wang, M. Wu, H. Huo, "Life cycle energy and greenhouse gas results of Fischer-Tropsch diesel produced from natural gas, coal,, and biomass," Center for Transportation Research, Argonne National Laboratory, presented at 2007 SAE Government/Industry meeting, Washington, DC, May 2007.

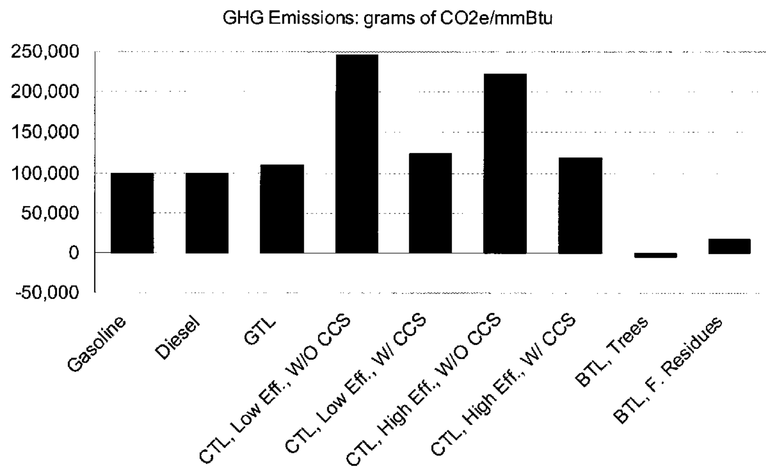


Figure 1. Life-cycle greenhouse gas results of Fischer-Tropsch diesel produced from natural gas, coal and biomass (GTL=gas-to-liquids, CTL=coal-to-liquids, CCS=carbon capture and sequestration, BTL=biomass-to-liquids, F=forest; emissions include CO_2, methane and N20). Wang et al., 2007.

These analyses show that using coal to produce a significant amount of liquid synfuel for transportation conflicts with the need to develop a low-CO_2 emitting transportation sector. The unavoidable fact is that liquid fuel made from coal contains essentially the same amount of carbon as is in gasoline or diesel made from petroleum. Given these results, it is not surprising that a recent Battelle study found that a significant coal-to-liquids industry is not compatible with stabilizing atmospheric CO_2 concentrations below twice the pre-industrial value. Battelle found that if there is no constraint on CO_2 emissions conventional petroleum would be increasingly replaced with liquid coal, but that in scenarios in which CO_2 concentrations are limited to 550 ppm or below, petroleum fuels are replaced with biofuels rather than liquid coal (Figure 2).[4]

Proceeding with liquid coal plants now could leave those investments stranded or impose unnecessarily high abatement costs on the economy if the plants continue to operate.

[4] J. Dooley, R. Dahowski, M. Wise, and C. Davidson, "Coal-to-Liquids and Advanced Low-Emissions Coal-fired Electricity Generation: Two Very Large and Potentially Competing Demands for US Geologic CO_2 Storage Capacity before the Middle of the Century." Battelle PNWD–SA–7804. Presented to the NETL Conference, May 9, 2007.

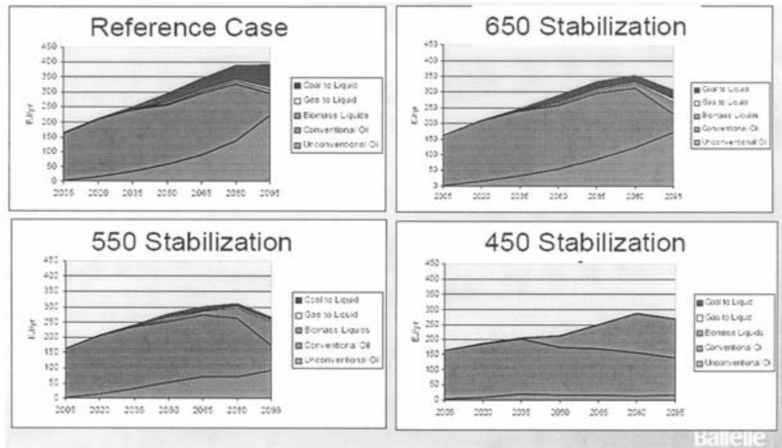


Figure 2. Conventional oil and alternative fuel supplies under four global warming emission limitation scenarios. Dooley et al., 2007.

Plug-in Hybrid Electric Vehicles

While NRDC believes there are better alternatives than using coal to replace gasoline, it is worth noting that making liquid fuels from coal is far less efficient and dirtier even than burning coal to generate electricity for use in plug-in hybrid vehicles (PHEVs). In fact, a ton of coal used to generate electricity used in a PHEV will displace about twice as much oil as using the same amount of coal to make liquid fuels, even using optimistic assumptions about the conversion efficiency of liquid coal plants.[5] The difference in CO_2 emissions is even more dramatic. Liquid coal produced with CCS and used in a hybrid vehicle would still result in life cycle greenhouse gas emissions of approximately 330 grams/mile, or ten times as much as the 33 grams/mile that could be achieve by a PHEV operating on electricity generated in a coal-fired power plant equipped with CCS.[6]

Coal and Biomass?

Some have proposed that a mixture of coal and biomass could be used to produce liquid fuel with a reduction in greenhouse gas emissions compared to today's fuels, assuming a high fraction of the CO_2 from the production plant is captured and permanently isolated in geologic formations. Proponents of this concept argue that using such a mixture of feedstocks to make liquid fuel could be compatible with cutting global warming emissions. It is important to recognize that such a combination does not actually reduce the emissions related to using coal; rather, the biomass component of the combination actually has negative net emissions that are deducted from the coal-related emissions to obtain low net emissions from the mixture. Moreover, even if the technical and economic challenges of making fuels with such a mixture could be met, a coal-biomass approach would still result in large amounts of additional coal mining and water requirements. With today's mining practices, mountaintop removal mining being the most egregious, launching a new fuel industry that depends on massive amounts of new mining without reform of our current practices would be a recipe for widespread environmental damage. As I discuss below, competition for water and even for low-cost coal supplies and geologic CO_2 storage reservoirs are additional factors that must be analyzed before we can con-

[5] Assumes production of 84 gallons of liquid fuel per ton of coal, based on the National Coal Council report. Vehicle efficiency is assumed to be 37.1 miles/gallon on liquid fuel and 3.14 miles/kWh on electricity.

[6] Assumes life cycle greenhouse gas emission from liquid coal of 27.3 lbs/gallon and life cycle greenhouse gas emissions from an IGCC power plant with CCS of 106 grams/kWh, based on R. Williams et al., paper presented to GHGT–8 Conference, June 2006.

clude that any significant use of coal for liquid fuels would be viable. Federal research could support such analyses. If Congress is going to legislate on the subject of liquid coal, the only responsible action now is to require a comprehensive comparative assessment of the full life cycle impacts and resource requirements of alternative approaches to reducing dependence on petroleum.

Conventional Pollution

Liquid coal fuel itself is expected to result in reduced emissions of conventional pollutants from vehicle exhausts. However, the same may not be true for liquid coal production plants. Conventional air emissions from liquid coal plants include sulfur oxides, nitrogen oxides, particulate matter, mercury and other hazardous metals and organics. While it appears that technologies exist to achieve high levels of control for all or most of these pollutants, the operating experience of liquid coal plants in South Africa demonstrates that liquid coal plants are not inherently "clean." If such plants are to operate with minimum emissions of conventional pollutants, performance standards will need to be written-standards that do not exist today in the U.S. as far as we are aware.

In addition, the various federal emission cap programs now in force would apply to few, if any, liquid coal plants.[7]

Thus, we cannot say today that liquid coal plants will be required to meet stringent emission performance standards adequate to prevent either significant localized impacts or regional emissions impacts.

Mining, Processing and Transporting Coal

The impacts of mining, processing, and transporting 1.1 billion tons of coal today on health, landscapes, and water are large. The industry's liquid coal vision advocates another 475 billion tons of coal production. To understand the implications of such an enormous expansion of coal production, it is important to have a detailed understanding of the impacts from today's level of coal production. The summary that follows makes it clear that we must find more effective ways to reduce these impacts before we follow a path that would result in even larger amounts of coal production and transportation.

Health and Safety

Coal mining is one of the U.S.'s most dangerous professions. The yearly fatality rate in the industry is 0.23 per thousand workers, making the industry about five times as hazardous as the average private workplace.[8] The industry had a low of 22 fatalities in 2005 but in 2006 there were 47 deaths.[9] Fatalities to date in 2007 are 17.[10] Coal miners also suffer from many non-fatal injuries and diseases, most notably black lung disease (also known as pneumoconiosis) caused by inhaling coal dust. Although the 1969 *Coal Mine Health and Safety Act* seeks to eliminate black lung disease, the United Mine Workers estimate that 1500 former miners die of black lung each year.[11]

Terrestrial Habitats

Coal mining—and particularly surface or strip mining—poses one of the most significant threats to terrestrial habitats in the United States. The Appalachian region,[12] for example, which produces over 35 percent of our nation's coal,[13] is one of the most biologically diverse forested regions in the country. But during surface mining activities, trees are clear-cut and habitat is fragmented, destroying natural areas that were home to hundreds of unique species of plants and animals. Even where forests are left standing, fragmentation is of significant concern because a decrease in patch size is correlated with a decrease in bio-diversity as the ratio of *interior* habitat to *edge* habitat decreases. This is of particular concern to certain bird

[7] The sulfur and nitrogen caps in EPA's "Clean Air Interstate Rule" ("CAIR") may cover emissions from liquid coal plants built in the eastern states covered by the rule but would not apply to plants built in the western states. Neither the national "acid rain" caps nor EPA's mercury rule would apply to liquid coal plants.

[8] Congressional Research Service, U.S. Coal: A Primer on the Major Issues, at 30 (Mar. 25, 2003).

[9] U.S. Department of Labor, Mine Safety and Health Administration, Coal Daily Fatality Report, *http://www.msha.gov/stats/charts/coaldaily.asp*, (visited September 1, 2007)

[10] *Id.*

[11] *http://www.umwa.org/blacklung/blacklung.shtml*

[12] Alabama, Georgia, Eastern Kentucky, Maryland, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia.

[13] Energy Information Administration. Annual Coal Report, 2004.

species that require large tracts of interior forest habitat, such as the black-and-white warbler and black-throated blue warbler.

After mining is complete, these once-forested regions in the Southeast are typically reclaimed as grasslands, although grasslands are not a naturally occurring habitat type in this region. Grasslands that replace the original ecosystems in areas that were surface mined are generally categorized by less-developed soil structure[14] and lower species diversity[15] compared to natural forests in the region. Reclaimed grasslands are generally characterized by a high degree of soil compaction that tends to limit the ability of native tree and plant species to take root. Reclamation practices limit the overall ecological health of sites, and it has been estimated that the natural return of forests to reclaimed sites may take hundreds of years.[16] According to the USEPA, the loss of vegetation and alteration of topography associated with surface mining can lead to increased soil erosion and may lead to an increased probability of flooding after rainstorms.[17]

The destruction of forested habitat not only degrades the quality of the natural environment, it also destroys the aesthetic values of the Appalachian region that make it such a popular tourist destination. An estimated one million acres of West Virginia mountains were subject to strip mining and mountaintop removal mining between 1939 and 2005.[18] Many of these mines have yet to be reclaimed so that where there were once forested mountains, there now stand bare mounds of sand and gravel.

The terrestrial impacts of coal mining in the Appalachian region are considerable, but for sheer size of the acreage affected, impacts in the western United States dominate the picture.[19] As of September 30, 2004, 470,000 acres were under federal coal leases or other authorizations to mine.[20] Unlike the East, much of the West—including much of the region's principal coal areas—is arid and predominantly unforested. In the West, as in the East, surface mining activities cause severe environmental damage as huge machines strip, rip apart and scrape aside vegetation, soils, wildlife habitat and drastically reshape existing land forms and the affected area's ecology to reach the subsurface coal. Strip mining results in industrialization of once quiet open space along with displacement of wildlife, increased soil erosion, loss of recreational opportunities, degradation of wilderness values, and destruction of scenic beauty.[21] Reclamation can be problematic both because of climate and soil quality. As in the East, reclamation of surface mined areas does not necessarily restore pre-mining wildlife habitat and may require scarce water resources be used for irrigation.[22] Forty-six western national parks are located within ten miles of an identified coal basin, and these parks could be significantly affected by future surface mining in the region.[23]

Water Pollution

Coal production causes negative physical and chemical changes to nearby waters. In all surface mining, the overburden (Earth layers above the coal seams) is removed and deposited on the surface as waste rock. The most significant physical effect on water occurs from valley fills, the waste rock associated with mountaintop removal (MTR) mining. Studies estimate that over 700 miles of streams were buried by valley fills from 1985–2001, and 1,200 miles were directly impacted by mountaintop removal and valley fills from 1992–2002.[24] Valley fills bury the headwaters of streams, which in the southeastern U.S. support diverse and unique habitats, and

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[14] Sencindiver, et al. "Soil Health of Mountaintop Removal Mines in Southern West Virginia". 2001.

[15] Handel, Steven. Mountaintop Removal Mining/Valley Fill Environmental Impact Statement Technical Study, Project Report for Terrestrial Studies. October, 2002.

[16] *Id.*

[17] EPA. Mountaintop Mining/Valley Fills in Appalachia: Draft Programmatic Environmental Impact Statement. 2003.

[18] Julian Martin, West Virginia Highlands Conservancy, Personal Communication, February 2, 2006.

[19] Alaska, Arizona, Colorado, Montana, New Mexico, North Dakota, Utah, Washington, and Wyoming.

[20] Bureau of Land Management, Public Land Statistics 2004, Table 3–18.

[21] See, e.g., U.S. Department of the Interior, Bureau of Land Management, 1985 Federal Coal Management Program/Final Environmental Impact Statement, pp. 210–211, 230–231, 241–242, 282 (water quality and quantity), 241, 251, 257.

[22] Bureau of Land Management. 3809 Surface Management Regulations, Draft Environmental Impact Statement. 1999.

[23] National Park Service, DOI. "Coal Development Overview." 2003.

[24] EPA. Mountaintop Mining/Valley Fills in Appalachia: Draft Programmatic Environmental Impact Statement.

regulate nutrients, water quality, and flow quantity. The elimination of headwaters therefore has long-reaching impacts many miles downstream.[25]

Coal mining can also lead to increased sedimentation, which affects both water chemistry and stream flow, and negatively impacts aquatic habitat. Valley fills in the eastern U.S., as well as waste rock from strip mines in the west add sediment to streams, as does the construction and use of roads in the mining complex. A final physical impact of mining on water is to the hydrology of aquifers. MTR and valley fills remove upper drainage basins, and often connect two previously separate aquifers, altering the surrounding groundwater recharge scheme.[26]

Acid mine drainage (AMD) is the most significant form of chemical pollution produced from coal mining operations. In both underground and surface mining, sulfur-bearing minerals common in coal mining areas are brought up to the surface in waste rock. When these minerals come in contact with precipitation and groundwater, an acidic leachate is formed. This leachate picks up heavy metals and carries these toxins into streams or groundwater. Waters affected by AMD often exhibit increased levels of sulfate, total dissolved solids, calcium, selenium, magnesium, manganese, conductivity, acidity, sodium, nitrate, and nitrite. This drastically changes stream and groundwater chemistry.[27] The degraded water becomes less habitable, non potable, and unfit for recreational purposes. The acidity and metals can also corrode structures such as culverts and bridges.[28] In the eastern U.S., estimates of the damage from AMD range from four to eleven thousand miles of streams.[29] In the West, estimates are between five and ten thousand miles of streams polluted. The effects of AMD can be diminished through addition of alkaline substances to counteract the acid, but recent studies have found that the addition of alkaline material can increase the mobilization of both selenium and arsenic.[30] AMD is costly to mitigate, requiring over $40 million annually in Kentucky, Tennessee, Virginia, and West Virginia alone.[31]

Air Pollution

There are two main sources of air pollution during the coal production process. The first is methane emissions from the mines. Methane is a powerful heat-trapping gas and is the second most important contributor to global warming after carbon dioxide. Methane emissions from coal mines make up between 10 and 15 percent of anthropogenic methane emissions in the U.S. According to the most recent official inventory of U.S. global warming emissions, coal mining results in the release of three million tons of methane per year, which is equivalent to 68 million tons of carbon dioxide.[32]

The second significant form of air pollution from coal mining is particulate matter (PM) emissions. While methane emissions are largely due to eastern underground mines, PM emissions are particularly serious at western surface mines. The arid, open and frequently windy region allows for the creation and transport of significant amounts of particulate matter in connection with mining operations. Fugitive dust emissions occur during nearly every phase of coal strip mining in the west. The most significant sources of these emissions are removal of the overburden through blasting and use of draglines, truck haulage of the overburden and mined coal, road grading, and wind erosion of reclaimed areas. PM emissions from diesel trucks and equipment used in mining are also significant. PM can cause serious respiratory damage as well as premature death.[33] In 2002, one of Wyoming's coal producing counties, Campbell County, exceeded its ambient air quality threshold several times, almost earning non-attainment status.[34] Coal dust problems in the West are likely to get worse if the administration finalizes its January 2006 proposal to exempt

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[25] *Id.*

[26] Keating, Martha. "Cradle to Grave: The Environmental Impacts from Coal." Clean Air Task Force, Boston. June, 2001.

[27] EPA Office of Solid Waste: Acid Mine Drainage Prediction Technical Document. December, 1994.

[28] EPA. Mountaintop Mining/Valley Fills in Appalachia: Draft Programmatic Environmental Impact Statement. 2003.

[29] EPA. Mid-Atlantic Integrated Assessment: Coal Mining. *http://www.epa.gov/maia/html/coal-mining.html*

[30] EPA. Mountaintop Mining/Valley Fills in Appalachia: Final Programmatic Environmental Impact Statement. 2005.

[31] *Id.*

[32] DOE/EIA, 2005. Emissions of Greenhouse Gases in the United States 2004. (December).

[33] EPA. Particle Pollution and Your Health. 2003.

[34] Casper [WY] Star Tribune, January 24, 2005.

mining (and other activities) from controls aimed at meeting the coarse PM standard.[35]

Coal Mine Wastes

Coal mining leaves a legacy of wastes long after mining operations cease. One significant waste is the sludge that is produced from washing coal. There are currently over 700 sludge impoundments located throughout mining regions, and this number continues to grow. These impoundment ponds pose a potential threat to the environment and human life. If an impoundment fails, the result can be disastrous. In 1972 an impoundment break in West Virginia released a flood of coal sludge that killed 125 people. In the year 2000 an impoundment break in Kentucky involving more than 300 million gallons of slurry (30 times the size of the Exxon Valdez spill) killed all aquatic life in a 20 mile diameter, destroyed homes, and contaminated much of the drinking water in the eastern part of the state.[36]

Another waste from coal mining is the solid waste rock left behind from tunneling or blasting. This can result in a number of environmental impacts previously discussed, including acid mine drainage. A common problem with coal mine legacies is the fact that if a mine is abandoned or a mining company goes out of business, the former owner is under no legal obligation to cleanup and monitor the environmental wastes, leaving the responsibility in the hands of the state.[37]

Effects on Communities

Coal mining can also have serious impacts on nearby communities. In addition to noise and dust, residents have reported that dynamite blasts can crack the foundations of homes,[38] and many cases of subsidence due to the collapse of underground mines have been documented. Subsidence can cause serious damage to houses, roads, bridges, and any other structure in the area. Blasting can also cause damage to wells, and changes in the topography and structure of aquifers can cause these wells to run dry.

Transportation of Coal Transporting coal from where it is mined to where it will be burned also produces significant quantities of air pollution and other environmental harms. Diesel-burning trucks, trains, and barges that transport coal release NO_X, SO_X, PM, VOCs (Volatile Organic Chemicals), CO, and CO_2 into the Earth's atmosphere. Trucks and trains (barge pollution data are unavailable) transporting coal release over 600,000 tons of NO_X, and over 50,000 tons of PM10 into the air annually.[39,40] In addition to health risks, black carbon from diesel combustion is another contributor to global warming.[41] Land disturbance from trucks entering and leaving the mine complex and coal dust along the transport route also release particles into the air.[42] For example, in Sylvester, West Virginia, a Massey Energy coal processing plant and the trucks associated with it spread so much dust around the town that "Sylvester's residents had to clean their windows and porches and cars every day, and keep the windows shut."[43] Even after a lawsuit and a court victory, residents—who now call themselves "Dustbusters"—still "wipe down their windows and porches and cars."[44]

Almost 60 percent of coal in the U.S. is transported at least in part by train and coal transportation accounts for 44 percent of rail freight ton-miles.[45] Some coal trains reach more than two miles in length, causing railroad-crossing collisions and pedestrian accidents (there are approximately 3,000 such collisions and 900 pedestrian accidents every year), and interruption in traffic flow (including emergency responders such as police, ambulance services, and fire departments). Local communities also have concerns about coal trucks, both because of their size and the dust they can leave behind. According to one report, in a Kentucky town, coal trucks weighing 120 tons with their loads were used, and "the Department of Transpor-

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[35] National Ambient Air Quality Standards for Particulate Matter, Proposed Rule, 71 Fed. Reg. 2620 (January 17, 2006); Revisions to Ambient Air Monitoring Regulations, Proposed Rule, 71 Fed. Reg. 2710 (January 17, 2006).

[36] Frazier, Ian. "Coal Country." *On Earth.* NRDC. Spring, 2003.

[37] Reece, Erik. "Death of a Mountain." *Harper's Magazine.* April, 2005.

[38] *Id.*

[39] DOT Federal Highway Administration. Assessing the Effects of Freight Movement on Air Quality, Final Report. April, 2005.

[40] Energy Information Administration: Coal Transportation Statistics.

[41] Hill, Bruce. "An Analysis of Diesel Air Pollution and Public Health in America." Clean Air Task Force, Boston. February, 2005.

[42] EPA. Mountaintop Mining/Valley Fills in Appalachia: Draft Programmatic Environmental Impact Statement. 2003.

[43] Michael Schnayerson, "The Rape of Appalachia," *Vanity Fair,* 157 (May 2006).

[44] *Id.*

[45] *http://nationalatlas.gov/articles/transportation/a_freightrr.html*

tation signs stating a thirty-ton carrying capacity of each bridge had disappeared."[46] Although the coal company there has now adopted a different route for its trucks, community representatives in Appalachia believe that coal trucks should be limited to 40 tons.[47]

Coal is also sometimes transported in a coal slurry pipeline, such as the one used at the Black Mesa Mine in Arizona. In this process the coal is ground up and mixed with water in a roughly 50:50 ratio. The resulting slurry is transported to a power station through a pipeline. This requires large amounts of fresh groundwater. To transport coal from the Black Mesa Mine in Arizona to the Mohave Generating Station in Nevada, Peabody Coal pumped over one billion gallons of water from an aquifer near the mine each year. This water came from the same aquifer used for drinking water and irrigation by members of the Navajo and Hopi Nations in the area. Water used for coal transport has led to a major depletion of the aquifer, with more than a 100 foot drop in water level in some wells. In the West, coal transport through a slurry pipeline places additional stress on an already stressed water supply. Maintenance of the pipe requires washing, which uses still more fresh water. Not only does slurry-pipeline transport result in a loss of freshwater, it can also lead to water pollution when the pipe fails and coal slurry is discharged into ground or surface water.[48] The Peabody pipe failed 12 times between 1994 and 1999. The Black Mesa mine closed as of January 2006. Its sole customer, the Mohave Generating Station, was shut down because its emissions exceeded current air pollution standards.

Water Requirements for Liquid Coal

Liquid coal production requires large quantities of water. According to a USGS report, thermal electric generation accounted for 39 percent of the freshwater withdrawn from watersheds in the U.S. in 2000.[49] The water use dedicated to liquid coal production will require water use above and beyond current uses, competing with other needs, including irrigation and public water supply. The withdrawal and consumption of water in areas with water shortages will be a major problem for this industry. Competing water uses, primarily for irrigation, will be a major problem in the West where water rights are established and water is considered a very valuable commodity. In the East, competing water uses, primarily from thermal electric cooling, and water shortages also are beginning to become an issue of concern.

There are three major uses of water in a coal-to-liquids plant, (1) process water, (2) boiler feed water and (3) cooling water. According to the Department of Energy's Idaho National Lab, approximately 12–14 barrels of water are used for every barrel of liquid coal.[50] Therefore the water requirement necessary to meeting the needs of an 80,000 BPD liquid coal plant could require sourcing about 40 million gallons of water per day (14 billion gallons per year). The 40 million gallons of water per day needed for an 80,000 BPD liquid coal facility is enough water to meet the domestic needs of more than 200,000 people,[51] or one-fifth the population of the State of Montana. There are already serious water supply problems in Western states such as Montana and Wyoming where most of our cheap coal supplies are located.

While alternative technologies exist that use less water in the liquid coal production process, many of them are more costly and some may be cost prohibitive. In addition, water must be of good quality for use in cooling towers and blow down operations and if water must be treated before use that will add additional costs to the plant operations Some research is suggesting the option of using coal bed methane water as an alternative water source and this is only possible if this water's salinity is low or if desalinization costs were low. According to NETL, much of the water produced from coal bed methane operations is very saline and needs to be treated prior to surface discharge or plant use.[52] Therefore, cost-effective sources of

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[46] Erik Reece, Lost Mountain: A Year in the Vanishing Wilderness 112 (2006).

[47] Personal communication from Hillary Hosta and Julia Bonds, Coal River Mountain Watch (Apr. 7, 2006).

[48] NRDC. Drawdown: Groundwater Mining on Black Mesa.

[49] USGS 2004. "Estimated Use of Water in the United States in 2000," USGS Circular 126. Available at *http://pubs.usgs.gov/circ/2004/circ1268/pdf/circular1268.pdf*

[50] Boardman, Richard, Ph.D. "Gasification and Water Nexus," Department of Energy, Idaho National Laboratory Gasification Research, presented March 14, 2007 at the GTC, Workshop on Gasification Technologies.

[51] Based on EPA's estimate of 200 gallons of water per person per day, *http://www.epa.gov/watrhome/you/chap1.html*

[52] DOE/NET–2006/1233 "Energy Issues for Fossil Energy and Water: Investigation of Water Issues Related to Coal Mining, Coal to Liquids, Oil Shale and Carbon Capture and Sequestration." June 2006.

water and technologies that use water more efficiently in these processes are limited.

Coal Resource Requirements

While it is frequently said that America has more than 250 years of coal to use, these claims are based current coal production of about one billion tons per year. As the National Academy of Sciences (NAS) has concluded, even with current consumption rates, it is "not possible to confirm" the 250 year supply claim because this estimate is based on "methods that have not been reviewed or revised since their inception in 1974" and that updated methods suggest that "only a small fraction of previously estimated reserves are actually minable reserves."[53]

These observations indicate we should reconsider proposals to legislate incentives and mandates for programs like liquid coal that would dramatically increase our rates of coal consumption. As mentioned above, if all of the coal industry's wish list for coal use were implemented, coal production would more than double. Apart from the environmental and health threats presented by this scenario, there are potentially large adverse economic impacts from a program to increase coal consumption on this scale.

Consider the following thought experiment. What would be the impact on U.S. recoverable coal reserves if we were to try to displace some significant fraction of U.S. oil imports with liquid coal? Current U.S. coal recoverable reserve estimates, using methods criticized by the NAS as possibly overstating actual minable coal, amount to just under 270 billion tons. Suppose the U.S. were to ramp up a liquid coal of size large enough to replace one-third to one hundred per cent of forecasted U.S. oil imports by 2030? U.S. EIA forecasts that net oil imports (crude and refined products) in 2030 will be about 16 million barrels a day.[54] Using the National Coal Council's estimate of conversion efficiency, to replace one-third of those imports would require consumption of nearly 1.2 billion tons of additional coal per year in 2030 and if oil import demand increased at two percent per year, by 2050 coal consumption to displace this same fraction of imports would grow to nearly 1.8 billion tons per year. When combined with continued use of coal for electric power, this rate of coal consumption would consume 40 percent of currently estimated recoverable reserves by 2050 and would deplete all of those reserves by about 2080.[55] If liquid coal production were scaled to a level needed to replace one-half of forecasted oil imports, 49 percent of estimated recoverable reserves would be consumed by 2050 and 100 percent by the year 2074 and if we tried to replace all of our forecasted oil imports with liquid coal then two-thirds of recoverable reserves would be consumed by 2050 and 100 percent by the year 2060.

The above is a thought experiment, not a prediction that we would actually run out of coal by those dates. Economists will argue that more reserves will become "recoverable" as the price rises. But as the argument suggests, such new reserves will be more expensive than today's coal supplies.

The point we must recognize is that using coal to make liquid fuel will at a minimum raise coal prices substantially for all uses, including the electric power industry, which now depends on coal to produce over 50 percent of U.S. electricity. It is also worth noting that the massive amounts of CO_2 that would have to be injected into geologic formations to limit emissions from liquid coal production will also drive up the cost of coal use. While it appears the U.S. has large amounts of geologic storage capacity, as with all resources there is a supply cost curve and with the large demand for storage capacity created by a significant liquid coal industry those costs will escalate faster than if demand is more moderate.

In short, there is no basis to assume that liquid coal would be an economic bargain either, providing one more reason for us to look for a better way.

A Responsible Action Plan

The impacts that a large liquid coal program could have on global warming pollution, conventional air pollution and damage from expanded coal production are substantial—so substantial that using coal to make liquid fuel would likely create far worse problems than it attempts to solve.

Fortunately, the U.S. can have a robust and effective program to reduce oil dependence without embracing liquid coal technologies. A combination of efficiency, renewable fuels and plug-in hybrid vehicles can reduce our oil consumption more

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[53] National Research Council, "Coal: Research and Development to Support National Energy Policy," Washington, DC, 2007 at 3.

[54] U.S. Energy Information Administration, "Annual Energy Outlook 2007."

[55] For this calculation we assume a one percent per year growth rate in coal consumption in the power sector. This is not a sustainable scenario but is chosen to illustrate the implications of "business as usual" practices.

quickly, more cleanly and in larger amounts than liquid coal even on the massive scale advocated by the coal industry.

A combination of more efficient cars, trucks and planes, biofuels, and "smart growth" transportation options outlined in report "Securing America," produced by NRDC and the Institute for the Analysis of Global Security, can cut oil dependence by more than three million barrels a day in 10 years, and achieve cuts of more than 11 million barrels a day by 2025, far outstripping the 2.6 million barrel a day program being promoted by the coal industry.

The Securing America program is made up of these sensible steps that will cut oil dependence, cut global warming emissions, and reduce other harmful impacts of today's energy production and consumption patterns:

Accelerate oil savings in passenger vehicles by:

- establishing tax credits for manufacturers to retool existing factories so they can build fuel-efficient vehicles and engineer advanced technologies, and
- establishing tax credits for consumers to purchase the next generation of fuel-efficient vehicles; and raising federal fuel economy standards for cars and light trucks in regular steps.

Accelerate oil savings in motor vehicles through the following:

- requiring replacement tires and motor oil to be at least as fuel efficient as original equipment tires and motor oil;
- requiring efficiency improvements in heavy-duty trucks; and
- supporting smart growth and better transportation choices.

Accelerate oil savings in industrial, aviation, and residential building sectors through the following:

- expanding industrial efficiency programs to focus on oil use reduction and adopting standards for petroleum heating;
- replacing chemical feedstocks with bioproducts through research and development and government procurement of bioproducts;
- upgrading air traffic management systems so aircraft follow the most-efficient routes; and
- promoting residential energy savings with a focus on oil-heat.

Encourage growth of the biofuels industry through the following:

- requiring all new cars and trucks to be capable of operating on biofuels or other non-petroleum fuels by 2015; and
- allocating $2 billion in federal funding over the next 10 years to help the cellulosic biofuels industry expand production capacity to one billion gallons per year and become self-sufficient by 2015.

Technologically Achievable Oil Savings (million barrels per day)

Oil Savings Measures	2015	2025
Raise fuel efficiency in new passenger vehicles through tax credits and standards	1.6	4.9
Accelerate oil savings in motor vehicles through		
fuel efficient replacement tires and motor oil	0.5	0.6
efficiency improvements in heavy-duty trucks	0.5	1.1
Accelerate oil savings in industrial, aviation, and residential sectors	0.3	0.7
Encourage growth of biofuels industry through demonstration and standards	0.3	3.9
Total Oil Saved	**3.2**	**11.2**

To cut our dependence on oil we should follow a simple rule: start with the measures that will produce the quickest, cleanest and least expensive reductions in oil use; measures that will put us on track to achieve the reductions in global warming emissions we need to protect the climate. If we are thoughtful about the actions we take, our country can pursue an energy path that enhances our security, our economy, and our environment.

People At Work

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Name	Title	Company	Address	First Rep...	Last Repo...	Conf...	Phone Number
BAHETHI, SARASWATI	DIRECTOR;SECRETARY;TREASURER	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	08/2007	10/2007	High	(301) 867-2000
BAHETHI, OM P	DIRECTOR;PRESIDENT	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	08/2007	10/2007	High	(301) 867-2000
BAHETHI, OM P	DIRECTOR	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	12/2004	10/2007	High	(301) 867-2000
MEHTA, ANOOP N	VICE PRESIDENT	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	12/2004	10/2007	High	(301) 867-2000
BAHETHI, SARASWATI	DIRECTOR	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	12/2004	10/2007	High	(301) 867-2000
BAHETHI, OM P	PRESIDENT	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	12/2004	10/2007	High	(301) 867-2000
BAHETHI, SARASWATI	SECRETARY	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	12/2004	10/2007	High	(301) 867-2000
BAHETHI, SARASWATI	TREASURER	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	12/2004	10/2007	High	(301) 867-2000
BAHETHI, SARASWATI	SECRETARY	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	11/2006	09/2007	High	(301) 867-2000
BAHETHI, OM P	PRESIDENT	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	11/2006	09/2007	High	(301) 867-2000
MEHTA, ANOOP		SCIENCE SYST...	10210 GREENBELT RD, STE 6...	07/2007	07/2007	High	(301) 867-2000
ESTES, RON	MEMBER	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	06/2007	06/2007	High	(301) 867-2000
UNDERWOOD, LAUREN W	SENIOR STAFF SCIENTIST	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	12/2006	12/2006	High	(301) 867-2000
ESTES, RONALD H	VICE PRESIDENT AND CHIEF OPERA...	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	11/2006	11/2006	High	(301) 867-2000
PEREDO, MAURICIO	DIRECTOR OF BUSINESS DEVELOPM...	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	11/2006	11/2006	High	(301) 867-2000
MEHTA, ANOOP N	VICE PRESIDENT AND CHIEF FINAN...	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	11/2006	11/2006	High	(301) 867-2000
BAHETHI, OM	PRESIDENT	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	11/2006	11/2006	High	(301) 867-2000
BAHETHI, SARA	MAJORITY OWNER	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	11/2006	11/2006	High	(301) 867-2000
MORRELL, AMY	WEB DEVELOPER AND SENIOR DAT...	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	10/2004	11/2005	High	(301) 867-2000
FALLOWS, LEN	PRESIDENT	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	08/2005	08/2005	High	(301) 867-2000
DISILVESTRE, SUSAN	HUMAN RESOURCES MANAGER	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	09/2004	09/2004	High	(301) 867-2000
IRISH, RICHARD	SENIOR SYSTEMS ENGINEER	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	05/2004	05/2004	High	(301) 867-2000
SCHEEL, HELLMUT	VICE PRESIDENT OF BUSINESS DEV...	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	12/2003	12/2003	High	(301) 867-2000
WAGENHOFER, JOSEPH	BUSINESS DEVELOPMENT MANAGER	SCIENCE SYST...	10210 GREENBELT RD, STE 6...	03/2002	03/2002	High	(301) 867-2000
MEHTA, ANOOP N, CPA		SCIENCE SYST...	10210 GREENBELT RD, STE 6...			High	(301) 867-2000
ESTES, RON	BRANCH MANAGER	SCIENCE SYST...	HAMPTON, VA	10/2007	10/2007	High	

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BAHETHI, OM P	PRES-CEO	SCIENCE SYST...	LANHAM, MD	10/2007	10/2007	High	
GABBAY, ALTAN	IT MGR	SCIENCE SYST...	LANHAM, MD	10/2007	10/2007	High	
STIENERT, OWEN	IT OPRS MGR	SCIENCE SYST...	LANHAM, MD	05/2007	10/2007	High	
MEHTA, ANOOP	V PRES	SCIENCE SYST...	LANHAM, MD	10/2006	10/2007	High	
BAHETHI, SARA	SEC	SCIENCE SYST...	LANHAM, MD	10/2006	10/2007	High	
GABBAY, ALTAN	IT MANANGEMENT	SCIENCE SYST...	LANHAM, MD	05/2007	10/2007	High	
BAHETHI, OM P	PRES	SCIENCE SYST...	LANHAM, MD	09/2006	10/2007	High	
DAN, CARL		SCIENCE SYST...	2880 BROADWAY, NEW YORK...	06/1997	07/2007	High	
BAHETHI, OM	CHAIRMAN OR CHIEF EXECUTIVE O...	SCIENCE SYST...	2880 BROADWAY, NEW YORK...	06/1997	07/2007	High	
DAN, CARL	PROCESS ADDRESS CONTACT	SCIENCE SYST...	2880 BROADWAY, STE 200, N...	06/1995	07/2007	High	
BAHETHI, OM P	PRESIDENT	SCIENCE SYST...	5900 PRINCESS GARDEN PKW...	10/2001	07/2007	High	(301) 731-9300
PEREDO, MAURICIO	MANAGER	SCIENCE SYST...	LANHAM, MD	05/2007	05/2007	High	
STIENERT, OWEN	IT OPERATIONS MANAGER	SCIENCE SYST...	LANHAM, MD	10/2006	05/2007	High	
DISILVESTRE, SUSAN	MANAGER	SCIENCE SYST...	LANHAM, MD	01/2005	05/2007	High	
ESTES, RONALD	MANAGER	SCIENCE SYST...	LANHAM, MD	09/2006	09/2006	High	
WOZNIAK, CARL	INTERNET MANAGER/WEBMASTER	SCIENCE SYST...	LANHAM, MD	09/2006	09/2006	High	
LAFRANCE, FLORENCE	OFFICE MANAGER	SCIENCE SYST...	LANHAM, MD	09/2006	09/2006	High	
SELVIG, LINDA	CORPORATE SECRETARY	SCIENCE SYST...	LANHAM, MD	09/2006	09/2006	High	
HALL, BRUCE	MANAGER/COORDINATOR	SCIENCE SYST...	LANHAM, MD	09/2006	09/2006	High	
BAHETHI, RAVI	IT MGR	SCIENCE SYST...	LANHAM, MD	09/2006	09/2006	High	
DUDLEY, CARROLL G	DIVISION MGR	SCIENCE SYST...	LANHAM, MD	09/2004	09/2006	High	
GAMBHIR, BRIJ	IT MANAGER	SCIENCE SYST...	LANHAM, MD	09/2004	09/2006	High	
WAGENHOFER, JOE	IT MANAGER	SCIENCE SYST...	LANHAM, MD	09/2004	09/2006	High	
HUFFMAN, GEORGE	IT MANAGER	SCIENCE SYST...	LANHAM, MD	09/2004	09/2006	High	
MEHTA, ANOOP N	CFO	SCIENCE SYST...	LANHAM, MD	10/2002	09/2006	High	
BAHETHI, SARA	SEC-TREAS	SCIENCE SYST...	LANHAM, MD	10/2002	09/2006	High	

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MARGERIN, BRUNO G	ENGINEER	SCIENCE SYST...	LANHAM, MD	07/2005	04/2006	High	
ESTES, RONALD	VP MARKETING	SCIENCE SYST...	LANHAM, MD	07/2005	04/2006	High	
SHAW, JIMMY	MARKETING MANAGER	SCIENCE SYST...	LANHAM, MD	09/2004	04/2006	High	
BAHETHI, RAVI	IT	SCIENCE SYST...	LANHAM, MD	06/2003	04/2006	High	
BAHETHI, OM P	PRESIDENT	SCIENCE SYST...	LANHAM, MD	10/2002	04/2006	High	
MARGERIN, BRUNO G	EAD SOFTWARE ENGINEER	SCIENCE SYST...	LANHAM, MD	09/2004	07/2005	High	
ESTES, RONALD	V.P. MARKETING	SCIENCE SYST...	LANHAM, MD	09/2004	07/2005	High	
SCHEEL, HELLMUT	CHIEF OPERATIONS OFFICER	SCIENCE SYST...	LANHAM, MD	09/2004	07/2005	High	
NESTRE, SUSAN	HR MGR	SCIENCE SYST...	LANHAM, MD	09/2004	07/2005	High	
SCHEEL, HELLMUT	CHIEF OPERATING OFFICER	SCIENCE SYST...	LANHAM, MD	01/2005	01/2005	High	
NESTRE, SUSAN	DIRECTOR OF HUMAN RESOURCES	SCIENCE SYST...	LANHAM, MD	01/2005	01/2005	High	
CLOSS, JAMES W	AGENT	SCIENCE SYST...	751 N 2ND ST, BAY SAINT LO...	01/2005	01/2005	High	
DISILVESTRE, SUSAN	HUMAN RESOURCES ADMINISTRAT...	SCIENCE SYST...	LANHAM, MD	09/2004	11/2004	High	
SHAW, JIMMY	DIRECTOR MARKETING	SCIENCE SYST...	LANHAM, MD	09/2004	11/2004	High	
AGUIRRA, LINDA	CONTROLLER	SCIENCE SYST...	LANHAM, MD	06/2003	05/2004	High	
WAGENHOFER, J	MANAGER	SCIENCE SYST...	LANHAM, MD	10/2002	05/2004	High	
MEHTA, ANOOP	DOMAIN ADMINISTRATIVE CONTACT	SCIENCE SYST...	5900 PRINCESS GARDEN PKW...	04/2002	12/2003	High	(301) 731-9300
RISHI, NARAIN	DOMAIN TECHNICAL CONTACT	SCIENCE SYST...	5900 PRINCESS GARDEN PKW...	04/2002	12/2003	High	(301) 731-9300
DISILVESTRE, SUE	HR MGR	SCIENCE SYST...	LANHAM, MD	06/2003	06/2003	High	
ELICA, ADRIAN	IS/MIS/IT ENGINEER	SCIENCE SYST...	LANHAM, MD	06/2003	06/2003	High	
SCHEEL, HELLMUT	HUMAN RESOURCE DIRECTOR	SCIENCE SYST...	LANHAM, MD	06/2003	06/2003	High	
DISILVESTRE, SUSAN M	GENERAL COUNSEL	SCIENCE SYST...	LANHAM, MD	06/2003	06/2003	High	
JONES, DIEDRE	HR ADMINISTRATOR	SCIENCE SYST...	LANHAM, MD	10/2002	10/2002	High	
GAMBHIR, BRIJ	DIVISION MANAGER	SCIENCE SYST...	LANHAM, MD	10/2002	10/2002	High	
FENNELL, MIKE	SR ACCOUNTANT	SCIENCE SYST...	LANHAM, MD	10/2002	10/2002	High	
NARAIN, RISHI	E-BUSINESS	SCIENCE SYST...	LANHAM, MD	10/2002	10/2002	High	

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AGUIRRA, LINDA	SUPV	SCIENCE SYST...	LANHAM, MD	10/2002	10/2002	High	
DUDLEY, CARROLL	DIVISION MANAGER	SCIENCE SYST...	LANHAM, MD	10/2002	10/2002	High	
BANKOV, ROMAN	IS/MIS/IT ADMINISTRATOR	SCIENCE SYST...	LANHAM, MD	10/2002	10/2002	High	
HUFFMAN, GEORGE	DIVISION MANAGER	SCIENCE SYST...	LANHAM, MD	10/2002	10/2002	High	
HUANG, FRANK	DIVISION MANAGER	SCIENCE SYST...	LANHAM, MD	10/2002	10/2002	High	
PRESNELL, CEIL	HUMAN RESOURCES MANAGER	SCIENCE SYST...	LANHAM, MD	10/2002	10/2002	High	
MARGERIN, BRUNO	SENIOR STAFF ENGINEER	SCIENCE SYST...	LANHAM, MD	10/2002	10/2002	High	
BAHETHI, RAVI	SYSTEMS ANALYST	SCIENCE SYST...	LANHAM, MD	10/2002	10/2002	High	
BAHETHI, OM PRAKASH		SCIENCE SYST...	4900 LISBOROUGH TER, BOW...	11/1995	09/2007	Med...	
BAHETHI, OM P		SCIENCE SYST...	4900 LISBOROUGH TER, BOW...	10/2002	10/2002	Med...	
KRAMER, SAUNDERS B, JR		SCIENCE SYST...		09/2000	06/2001	Med...	
HERATH, LAWRENCE W		SCIENCE SYST...		09/2000	10/2000	Med...	
BAHETHI, OM PRAKASH		SCIENCE SYST...	4900 LISBOROUGH TER, BOW...	05/2000	05/2000	Med...	
MACK, DOROTHY		SCIENCE SYST...	8804 CIPRIANO CT, LANHAM,...	04/2002	09/2007	Low	
MACK, CHARLES E		SCIENCE SYST...	8804 CIPRIANO CT, LANHAM,...	10/2001	09/2007	Low	
JACKSON, DOROTHY		SCIENCE SYST...	8804 CIPRIANO CT, LANHAM,...	10/2001	09/2007	Low	
BAHETHI, RAVI P		SCIENCE SYST...	4900 LISBOROUGH TER, BOW...	11/1995	09/2007	Low	
BAHETHI, SARASWATI		SCIENCE SYST...	4900 LISBOROUGH TER, BOW...	11/1995	09/2007	Low	
JACKSON, WAINWRIGHT		SCIENCE SYST...	8804 CIPRIANO CT, LANHAM,...	06/2004	08/2007	Low	
MANSINGKA, NAMITA		SCIENCE SYST...	4900 LISBOROUGH TER, BOW...	02/2007	07/2007	Low	
BAHETI, S D		SCIENCE SYST...	8804 CIPRIANO CT, LANHAM,...	11/2000	07/2007	Low	
BAHETI, KIRTI		SCIENCE SYST...	8804 CIPRIANO CT, LANHAM,...	07/2000	07/2007	Low	
BAHETI, ASHISH		SCIENCE SYST...	8804 CIPRIANO CT, LANHAM,...	01/1998	07/2007	Low	
BAHETI, POOJA		SCIENCE SYST...	8804 CIPRIANO CT, LANHAM,...	08/1994	07/2007	Low	
WAINWRIGHT, JACKSON		SCIENCE SYST...	8804 CIPRIANO CT, LANHAM,...	06/2004	01/2006	Low	
CHARLES, MACK		SCIENCE SYST...	8804 CIPRIANO CT, LANHAM,...	02/2003	02/2003	Low	

People At Work

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Name	Title	Company	Address	First Rep...	Last Repo...	Conf...	Phone Number
BARET, SUSHILA		SCIENCE SYST...	8804 CIPRIANO CT, LANHAM,...	08/2001	01/2002	Low	
BAHETHI, PRAVEEN P		SCIENCE SYST...	4900 LISBOROUGH TER, BOW...	11/1995	10/2000	Low	
NAINSHEH, BRANBRATT		SCIENCE SYST...	8804 CIPRIANO CT, LANHAM,...	11/1998	01/1999	Low	
SAYEED, ADMED		SCIENCE SYST...	8804 CIPRIANO CT, LANHAM,...	01/1988	12/1990	Low	
PANGARKAR, MADHAV G		SCIENCE SYST...	8804 CIPRIANO CT, LANHAM,...	01/1983	04/1986	Low	
BAHETHI, OM P		SCIENCE SYST...	8804 CIPRIANO CT, LANHAM,...	01/1983	02/1985	Low	
MANTRI, TARA CHAND		SCIENCE SYST...	8804 CIPRIANO CT, LANHAM,...	06/1984	06/1984	Low	
PARKER, JOHN C, III		SCIENCE SYST...	8804 CIPRIANO CT, LANHAM,...	04/1984	04/1984	Low	

BIOGRAPHY FOR DAVID G. HAWKINS

David G. Hawkins began his work in "public interest" law upon graduation from Columbia University Law School in 1970. He joined the Natural Resources Defense Council's Washington, DC office in 1971 as one of the organization's first staff members.

In 1977, Mr. Hawkins was appointed by President Carter to be Assistant Administrator for Air, Noise, and Radiation at the Environmental Protection Agency. During his time at EPA, he was responsible for initiating major new programs under the 1977 *Amendments to the Clean Air Act.*

With President Reagan's election in 1981, Mr. Hawkins returned to NRDC to co-direct NRDC's Clean Air Program.

In 1990, Mr. Hawkins became Director of NRDC's Air and Energy Program, and in 2001 he became the Director of NRDC's Climate Center. The Climate Center focuses on advancing policies and programs to reduce the pollution responsible for global warming. In addition to working with Congress to design a legislative mechanism that will slow, stop and reduce the emissions of global warming pollution, Mr. Hawkins is recognized as an expert on advanced coal technologies and carbon dioxide capture and storage.

Mr. Hawkins currently serves on the boards of the Center for Clean Air Policy, Resources for the Future and the Board on Environmental and Energy Systems of the National Academy of Sciences. He is also a member of the U.S. Department of Energy's Climate Change Science Program Product Development Advisory Committee. Mr. Hawkins participated in the Intergovernmental Panel on Climate Change's Special Report on Carbon Dioxide Capture and Storage and is participating in the IPCC's Fourth Assessment Report on climate change.

Mr. Hawkins is married with three children and lives in Bethesda, MD.

Chairman LAMPSON. Thank you, Dr. Hawkins.

Dr. Romm.

STATEMENT OF DR. JOSEPH ROMM, FORMER ACTING ASSISTANT SECRETARY, OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY, DEPARTMENT OF ENERGY; SENIOR FELLOW, CENTER FOR AMERICAN PROGRESS

Dr. ROMM. Thank you. Thank you, Mr. Chairman and Members of the Committee. I appreciate the opportunity to share my views on liquid coal.

I will—just two key questions. First, should Congress promote coal as a transportation fuel? And second, if Congress does, will people actually drive their cars with liquid coal? I think the answer to both questions is decidedly no.

Congress should really promote only those technologies and strategies that provide significant and net societal benefit. Liquid coal does not provide net societal benefit. Worse, it will actually cause societal harm. Liquid coal would increase greenhouse gas emissions, use up increasingly scarce water supplies, and divert hundreds of billions of dollars from crucial clean energy solutions.

We simply have run out of time to waste money and resources on liquid coal because global warming is happening faster than scientists had warned. Sea ice loss, ice sheet loss, temperature rise, sea level rise, hurricane intensity, and expansion of the tropics, all of them are happening faster than scientists expected.

We all want to avoid catastrophic warming such as 80 foot sea level rise, and that means limiting future warming to two degrees Fahrenheit, and that requires mandatory cuts in greenhouse gas emissions of 60 to 80 percent by 2050, as many bills before Congress would require. And it certainly doesn't make any sense for Congress to pursue on the one hand reducing fossil fuel, CO_2 emis-

sions dramatically on the one hand and then on the other hand significantly promoting it with coal-to-liquids.

It is true that carbon dioxide emissions that, as Dr. Hawkins said, carbon dioxide emissions from coal to diesel are about double that of conventional diesel. It is true that you could possibly capture the carbon dioxide and store it underground permanently, but that will make an expensive and complicated process even more expensive and complicated so it seems unlikely for the foreseeable future.

I would also add that there is no evidence whatsoever that this country is at all serious about carbon capture and storage. If we were serious about carbon capture and storage, we would be doing decidedly different things. We would have a price for carbon dioxide, without which there will be no carbon capture and storage, and we would start identifying and certifying repositories for carbon capture, for carbon storage, which we haven't even begun doing.

I would also add as I explained in my testimony, that using carbon dioxide for enhanced oil recovery is not sequestration. Why? Because the carbon dioxide squeezes more oil out of the ground. You then burn that oil, and you release the carbon dioxide again. So you haven't accomplished anything.

I would also add, and this is important, that when you are done with the carbon capture and storage, if you happen to do it, you are still left with diesel fuel, which is a carbon-intensive liquid fuel that will release its carbon into the atmosphere once it is burned in an internal combustion engine. We are going to need to reduce diesel consumption and all liquid petroleum consumption 60 to 80 percent by mid century. So we don't need to figure out ways to increase it.

The future of coal in a carbon-constrained world is not liquefaction plus carbon capture and storage. The future of coal is electricity generation with carbon capture and storage since that is carbon free. A 2006, study by the University of California found that a significant use of coal to diesel could increase annual emissions by seven billion tons of carbon dioxide for several decades. That is more than current U.S. carbon emissions and would certainly be fatal to any effort to avoid catastrophic warming.

Instead of liquid coal, Congress needs to address the climate problem by establishing a cap on emissions that creates a price for carbon dioxide. What would be the impact of that cap when you ultimately put it in place? The U.S. Energy Information Administration has actually done a number of studies on this. In one analysis EIA modeled a carbon dioxide permit price reaching only $14 in 2030, a relatively low price, considerably lower than the current price for carbon dioxide in Europe. Yet this low price reduced projected liquid coal production by 85 percent in 2030.

A second EIA analysis showed that even a moderate price for carbon dioxide wipes out all projected liquid coal plants. So Congress is going to be passing laws in the next few years that are essentially going to render all liquid coal uneconomic.

Coal-to-liquid is just a dead end from a climate perspective and from a water perspective, too. You have heard what Dr. Hawkins said. We are in a world that is facing mega droughts and chronic water shortages from human-caused climate change, and in fact,

water demand is one reason chronically-water-short China has raised the capital threshold for liquid coal projects in an effort to scale back growth.

Time has simply run out in the race to avoid catastrophic warming. We no longer have the luxury of grossly misallocating capital and fuels to expensive boondoggles like coal-to-liquid. Liquid coal will not have a future in this country, no matter how much money Congress squanders on it. I think Congress should not allocate significant funds to liquid coal, R&D, or other measures to promote liquid coal. The future of coal in the carbon-constrained world, again, is in the form of electricity generation with carbon capture and storage.

And as Dr. Hawkins said, if coal has a future as a transportation fuel, it is with plug-in hybrids running on zero carbon electricity generated from coal with carbon capture and storage.

Thank you.

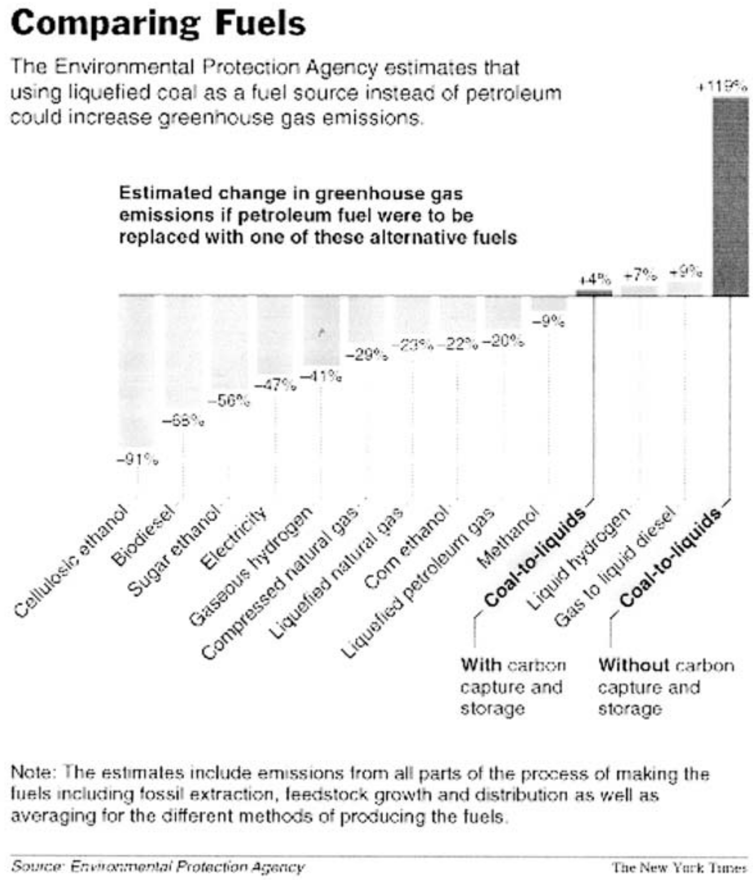
[The prepared statement of Dr. Romm follows:]

PREPARED STATEMENT OF JOSEPH ROMM

Mr. Chairman, Members of the Committee, I am delighted to appear before you today to discuss the subject of liquid fuel from coal. I am a Senior Fellow at the Center for American Progress here in Washington, DC where I run the blog *ClimateProgress.org*. I am author of the recent book *Hell and High Water: Global Warming—the Solution and the Politics* (Morrow, 2007) and have published and lectured widely on energy and climate issues.

I served as Acting Assistant Secretary at the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy during 1997 and Principal Deputy Assistant Secretary from 1995 though 1998. In that capacity, I helped manage the largest program in the world for working with businesses to develop and use clean energy technologies. I hold a Ph.D. in physics from M.I.T.

We are all grappling with how best to avoid catastrophic global warming. I will argue coal-to-liquids is not part of the solution—and would in fact make the problem worse. The following figure, based on EPA data, shows the estimated change in greenhouse gas emissions from various alternative fuels:



I appreciate the opportunity to share my views on coal-to-liquids, which are based on numerous discussions with leading energy experts; research and analysis for my book and for the National Commission on Energy Policy; and participation in the Defense Science Board Task Force on Department of Defense Energy Strategy, which heard a number of briefings on liquid coal, including from the Jason's defense advisory group. All references in this testimony can be found in my book or on my blog.

BACKGROUND

The question of the role of coal-to-liquids can play in the national energy mix can be understood only with a full appreciation of the scale of climate mitigation the Nation and the world must pursue. Global concentrations of carbon dioxide, the primary greenhouse gas, are rising at an accelerating rate in recent years—and they are already higher than at any time in the past three million years. The scientific consensus, as reflected in the work of the Intergovernmental Panel on Climate Change (IPCC), appears to be seriously *underestimating* the rate of climate change:

- "The recent [Arctic] sea-ice retreat is larger than in any of the (19) IPCC [climate] models"—and that was a Norwegian expert in 2005. The retreat has accelerated in the past two years.
- The ice sheets appear to be shrinking "100 years ahead of schedule." That was Penn State climatologist Richard Alley in March 2006. In 2001, the IPCC

thought that neither Greenland nor Antarctica would lose significant mass by 2100. They both already have.

- The temperature rise from 1990 to 2005—0.33°C—was "near the top end of the range" of IPCC climate model predictions.
- Sea-level rise from 1993 and 2006—3.3 millimeters per year as measured by satellites—was higher than the IPCC climate models predicted.
- Atlantic hurricane intensity appears to be increasing faster than the models projected.
- The tropics are expanding faster than the models project.
- Since 2000, carbon dioxide emissions have grown faster than any IPCC model had projected.

Worse, the ocean's heat content will keep re-radiating heat into the Earth's atmosphere even after we eliminate the heat imbalance, meaning the planet will keep warming and the glaciers keep melting for decades after we cut greenhouse gas emissions. Therefore, we *must* act in an "anticipatory" fashion and reduce emissions long before climate change is painfully obvious to everyone.

The planet has warmed about 0.8°C since the mid-19th century, primarily because of human-generated greenhouse gas emissions. If we don't sharply reverse the increase in global greenhouse gas emissions within the next decade, we will be committing the world to an additional 2° to 3°C warming by century's end, temperatures not seen for millions of years, when Greenland and much of Antarctica were ice free, and *sea levels were 80 feet higher.*

How fast can the sea level rise? Following the last ice age, the world saw sustained melting that *raised sea levels more than a foot a decade.* NASA's Dr. James Hansen—the country's leading climate scientist—believes we could see such a catastrophic melting rate within the century, as do many others I interviewed for my book. Other potential devastating threats from unrestricted greenhouse gas emissions include widespread drought and desertification, including in the American southwest, and an increase in extreme weather of all kinds, including heat waves, hurricanes, and severe rainstorms.

To avoid this fate, we must sharply reduce global carbon dioxide emissions from fossil fuel combustion. As an example of the kind of reductions required by climate change, both Florida Governor Charlie Crist and California Governor Arnold Schwarzenegger have committed their states to reduce greenhouse gas emissions to *80 percent below 1990 levels by 2050.* The United States Climate Action Partnership—a group of Fortune 500 companies and leading environmental organizations—has embraced 60 percent to 80 percent cuts by 2050. Former Prime Minister Tony Blair committed the United Kingdom to a 60 percent reduction by 2050. The IPCC says all industrialized nations, including the United States, need to achieve reductions of 50 percent to 80 percent to avoid the worst of global warming—and that requires emissions to peak in the next decade. Many bills have been introduced to Congress to achieve such cuts. The question is where does liquid coal fit in U.S. efforts to achieve such cuts?

NO ROLE FOR LIQUID COAL

Coal and natural gas can be converted to diesel fuel using the Fischer-Tropsch process. During World War II, coal gasification and liquefaction produced more than half of the liquid fuel used by the German military. South Africa has employed this process for decades.

The process is not more widely used today in large part because it is incredibly expensive. It costs $5 billion or more just to build a plant capable of producing 80,000 barrels of oil a day (the U.S. currently consumes more than 21 million barrels a day).

Five to seven gallons of water are necessary for every gallon of diesel fuel that's produced (and double that if you co-produce diesel fuel and electricity from coal), according to the June 2006 report, "Emerging Issues for Fossil Energy and Water: Investigation of Water Issues Related to Coal Mining, Coal to Liquids, Oil Shale, and Carbon Capture and Sequestration" by DOE's National Energy Technology Laboratory. Here is the key figure from the report:

Table 2-1. Water Requirements for Coal Liquefaction Plants.

Technology	Coal	Size	Water Requirement
Indirect Liquefaction	Eastern	50,000 BPSD	10,500 GPM (4.966 Bgal/yr)
Indirect Liquefaction	Western	50,000 BPSD	7,300 GPM (3.453 Bgal/yr)
Direct Liquefaction	Midwestern	50,000 BPSD	7,900 GPM (3.737 Bgal/yr)
Coproduction (F-T Liquids Plus Electric Power)	Eastern	25,000 BPSD plus 1,250 MW	20,800 GPM (9.839 Bgal/yr)

Source: Parsons 2005.

This is not a particularly good long-term strategy in a nation and a world facing mega-droughts and chronic water shortages from human-caused climate change. The heavy water demand is one reason chronically water-short China has raised the capital threshold for liquid coal projects in an effort to scale back growth.

Worse than the water issue, the total carbon dioxide emissions from coal-to-diesel are about double that of conventional diesel, as the earlier figure shows. It is possible to capture the carbon dioxide from the process and store it underground permanently. But that will make an expensive process even more expensive, so it seems unlikely for the foreseeable future, certainly not until carbon dioxide is regulated and has a high price and we have a number of certified underground geologic repositories.

More importantly, even with the capture and storage of CO_2 from the Fischer-Tropsch process, the final product is diesel fuel, a carbon-intensive liquid that will release CO_2 into the atmosphere once it is burned in an internal combustion engine. A great many people I have spoken to are confused about this point: They think that capturing and storing the CO_2 while turning coal to diesel is as good an idea as capturing the CO_2 from the integrated gasification combined cycle (IGCC) process for turning coal into electricity. No. The former process still leaves a carbon-intensive fuel, whereas the latter process yields near zero-carbon electricity.

The future of coal in a carbon-constrained world is electricity generation with carbon capture and storage, not CTL plus carbon capture and storage. Capturing and storing even one gigaton of carbon a year requires a flow of carbon dioxide *into* the ground equal to the current flow of oil *out* of the ground. That by itself represents an enormous engineering challenge. We need to devote the vast majority of this level of sequestration effort to power production, to generation of zero-carbon electricity from coal, not to generation of an endless stream of carbon-intensive liquid fuel like Fischer-Tropsch diesel. Worse, some people propose taking the captured CO_2 and using it for enhanced oil recovery, which, as discussed below, is the equivalent of not capturing the carbon dioxide at all.

Coal to diesel is a bad idea for the Nation and the planet. If the United States pursues it aggressively, catastrophic climate change will be all but unavoidable. Turning natural gas into diesel is not as bad an idea, at least from the perspective of direct emissions, because natural gas is a low-carbon fuel. But it represents a tremendous misuse of natural gas, which could otherwise be used to reduce future greenhouse gas emissions.

A 2006 study by the University of California at Berkeley found that meeting the future demand shortfall from conventional oil with unconventional oil, especially coal-to-diesel, could increase annual emissions by 2.0 billion metric tons of carbon (7.3 gigatons of carbon dioxide) for several decades. That is more than current total U.S. carbon emissions and would certainly be fatal to any effort to avoid 3°C increase in average worldwide temperature. Indeed, in a liquid coal scenario, a tripling of carbon dioxide emissions by century's end seems likely, which would likely leave the planet 5°C warmer than preindustrial levels by 2100—a temperature not seen since before Antarctica had ice, when sea levels were 280 feet higher than current levels. Again, avoiding 3°C requires a substantial *decrease* in total upstream and downstream carbon emissions from oil by mid-century.

EIA PREDICTS CARBON PRICE FATAL TO LIQUID COAL

Instead of promoting of liquid coal, Congress must address the climate problem by establishing a cap on emissions that creates a price for carbon dioxide. What will be the impact on liquid coal of a carbon cap? Two recent reports by the U.S. Energy Information Administration (EIA) provide the answer.

In its January 2007 report, *"Energy Market and Economic Impacts of a Proposal to Reduce Greenhouse Gas Intensity with a Cap and Trade System,"* EIA examined the impact of a draft version of Sen. Jeff Bingaman's global warming bill. That bill has a safety valve, which limits the price of carbon dioxide permits. In the EIA analysis, the permit price starts around $4 a ton of carbon dioxide in 2012, rises to $7.15 in 2020 and reaches only $14.18 in 2030. *This is a relatively low price for carbon dioxide.* Indeed, this 2030 price is considerably lower than the current price for carbon dioxide in the European Union—and the first budget year for Kyoto isn't even until next year. In this scenario, EIA finds:

> in 2020, CTL production is 0.2 million barrels per day (*74 percent*) lower than in the reference case. By 2030, the change is 0.6 million barrels per day (*85 percent*) lower than in the reference case.

In short, a relatively low price for carbon dioxide wipes out the vast majority of projected CTL.

In July 2007, EIA released *"Energy Market and Economic Impacts of S. 280, the Climate Stewardship and Innovation Act of 2007,"* an analysis of the global warming bill by Senators John McCain and Joe Lieberman. S. 280 sets considerably more stringent reduction targets than Sen. Bingaman's draft bill—ultimately reaching 60 percent below 1990 emissions levels by 2050. This bill has no safety valve. As a result, the permit price reaches $22.20 in 2020 and hits $47.90 in 2030. The report finds:

> **None of the 15 coal-to-liquids plants built in the reference case are projected to come on line in the main S. 280 cases.** In the reference case [business as usual], coal consumption at CTL plants reaches 109 million tons in 2030.

A moderate price for carbon dioxide wipes out all projected CTL.

Since it is all but inevitable that we will have a low-to-moderate price of carbon dioxide by 2020, and at least a moderate price by 2030, CTL will not achieve any significant market penetration. No amount of federal research and development investment or tax credits or loan guarantees are likely to change that equation.

CTL FOR ENHANCED OIL RECOVERY DOES NOT HELP THE CLIMATE

The carbon dioxide from CTL could be used to squeeze more oil out of the ground by injecting it into a well where it would be sequestered permanently. It might be argued that the carbon dioxide could have dual value—for enhanced oil recovery (EOR) and as a certified greenhouse gas emission reduction—and that such a dual value would make CTL more economical.

That, however, makes neither environmental nor economic sense. The key ratio is carbon dioxide injected vs. carbon dioxide released from recovered oil. BP and UCLA did such a life cycle analysis in 2001 and concluded, "the EOR activity is almost carbon-neutral when comparing net storage potential and gasoline emissions from the additional oil extracted." And that may be optimistic. The study notes:

> The results presented reflect only gasoline consumption but do not take into account the additional emissions that would originate from the refining process, nor the emissions arising from the combustion of the other products of crude oil such as diesel, bunker or jet fuels.

In short, the carbon dioxide used to recover the oil is less than the carbon dioxide released from that oil when you include the carbon dioxide released from 1) burning all the refined products and 2) the refining process itself. For that reason, no nation should give carbon credits for carbon dioxide used for EOR.

The study, however, has a different conclusion: "utilizing captured and recycled CO_2 *instead of using CO_2 exclusively from natural reservoirs* reduces greenhouse gas emissions to the atmosphere from EOR" (emphasis added). This is true because most carbon dioxide used for EOR today comes from "natural reservoirs."

But the Nation and the world have barely touched the full potential of EOR even though it can potentially double the oil output from a well that has undergone primary and secondary recovery. Why? As a 2005 Department of Energy press release on an EOR-sequestration project noted, "much of the CO_2 used in similar U.S. EOR projects has been taken at *considerable expense* from naturally occurring reservoirs" (emphasis added).

Cheap, widely available carbon dioxide would be a game-changer for oil recovery. The DOE carefully studied EOR and came to an amazing conclusion in 2006. In the U.S. alone, "next generation CO_2-EOR technology" and "widespread sequestration of industrial carbon dioxide" could add a stunning "160 billion barrels of domestic oil recovery." The combustion of that oil would produce more than 60 billion tonnes of CO_2, equivalent to ten times annual U.S. CO_2 emissions.

A CTL project where the carbon dioxide is captured and used for new EOR is a doubly bad idea from a climate perspective. Nor does it solve the problem of oil dependency. As President Bush has said, "we are addicted to oil" and "we need to get off oil." Achieving those goals while sharply reducing greenhouse gas emissions can be accomplished only with cars that are significantly more fuel-efficient running on low-carbon alternative fuels, such as cellulosic ethanol or electricity from zero-carbon sources for plug-in hybrid electric vehicles.

CONCLUSION

We are simply running out of time to avoid catastrophic warming, and we no longer have the luxury of grossly misallocating capital and fuels to expensive boondoggles like coal-to-liquid. Because of the urgent need to reduce greenhouse gas emissions—because Congress is finally considering the passage of a cap and trade system to reduce emissions—CTL should have little future in this country.

Congress should certainly not allocate significant funds to CTL R&D, nor should it take other measures to promote CTL. The future of coal in a carbon constrained world is in the form of electricity generation with carbon capture and storage. And if coal has a future as a transportation fuel, it is with plug in hybrids running on such zero-carbon coal electricity. For these reasons, accelerating the transition to such zero-carbon power is where Congress should be focusing its time and resources.

BIOGRAPHY FOR JOSEPH ROMM

Dr. Joseph Romm is one of the world's leading experts on clean energy technologies and greenhouse gas mitigation. He is a senior fellow at the Center for American Progress, where he oversees the blog *ClimateProgress.org.* He is author of the book *Hell and High Water: Global Warming-the Solution and the Politics* (Morrow, 2007). Dr. Romm is coauthor of the *Scientific American* article, "Hybrid Vehicles Gain Traction" (April 2006), and author of the report, "The Car and Fuel of the Future: A Technology and Policy Overview," for the National Commission on Energy Policy (July 2004). His previous book, *The Hype About Hydrogen: Fact and Fiction in the Race to Save the Climate,* was named one of the best science and technology books of 2004 by *Library Journal.*

Dr. Romm served as Acting Assistant Secretary at the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy during 1997 and Principal Deputy Assistant Secretary from 1995 though 1998. In that capacity, he helped manage the largest program in the world for working with businesses to develop and use clean energy technologies—one billion dollars aimed at hybrid vehicles, electric batteries, hydrogen and fuel cell technologies, all forms of renewable energy, distributed generation, energy efficiency in buildings and industry, and biofuels.

Romm initiated, supervised, and publicized a comprehensive technical analysis by five national laboratories of the energy technologies best able to reduce greenhouse gas emissions cost-effectively, "The Five Lab Study." He helped lead the development of the Administration's climate technology strategy. He is also author of the first book to benchmark corporate best practices for using clean energy technologies to reduce greenhouse gas emissions: *Cool Companies: How the Best Businesses Boost Profits and Productivity by Cutting Greenhouse Gas Emissions.*

Dr. Romm is Executive Director and founder of the Center for Energy and Climate Solutions—a one-stop shop helping businesses and states adopt high-leverage strategies for saving energy and cutting pollution. The Center is a division of the Virginia-based nonprofit, Global Environment & Technology Foundation. Romm's clients have included Toyota, IBM, Johnson & Johnson, Collins Pine, Nike, Timberland, Texaco, and Lockheed-Martin.

Romm holds a Ph.D. in physics from M.I.T. He has written and lectured widely on clean energy and climate issues, including articles in *Forbes, Technology Review, Issues in Science and Technology, Foreign Affairs, The New York Times, the L.A. Times, Houston Chronicle, Washington Post,* and *Science* magazine. He co-authored "Mid East Oil Forever," the cover story of the April 1996 issue of the *Atlantic Monthly,* which predicted higher oil prices within a decade and discussed alternative energy strategies.

Chairman LAMPSON. Thank you, Dr. Romm.

Now, Dr. Boardman.

STATEMENT OF DR. RICHARD D. BOARDMAN, SENIOR CONSULTING RESEARCH AND DEVELOPMENT LEAD, IDAHO NATIONAL LABORATORY

Dr. BOARDMAN. I am honored to be invited to contribute to the discussion about the benefits and challenges of converting coal into liquid transportation fuels.

I have submitted a lengthy testimony to you, but time will not permit me to draw your attention but only to a very few of the most selling points in that document. My remarks are based on my personal and professional knowledge and do not reflect the views of the Department of Energy (DOE).

Please direct your attention, if you would, please, to the drawing in the lengthy document on page 6 of my testimony, which shows the life cycle of carbon obtained from biomass and coal when it is utilized to produce synthetic fuels, electric power, and chemical products. This figure depicts the plan that Baard Energy is developing for a site in Ohio.

Baard Energy and the Idaho National Lab (INL) entered into a cooperative research and development agreement to study a coal-to-liquids plant similar to the figure you are viewing, using the majority of coal with a smaller portion of biomass.

Now please turn your attention to the summary table on page 5. The top row shows the amount of greenhouse gas released when transportation fuels are produced from Arabian crude. The second row shows the greenhouse gas emissions calculated by DOE NETL for a hypothetical coal-to-liquids plant. The third row shows the greenhouse gas emissions calculated by INL for the Baard energy Ohio project before any controls for greenhouse gas emissions are implemented. The remaining rows show various levels of greenhouse gas reduction that can be attained by implementing carbon capture and sequestration and by co-feeding only 30 percent biomass to the coal gasifier.

As you can see from this table, it is possible to reduce greenhouse gas emissions by up to 46 percent below comparable crude emissions when the coal-to-liquids plants are operated in this manner.

I wish to leave you with three factual points with respect to the exemplary Baard energy plant design. First, gasification and coal and biomass plans is technically feasible and commercially proven and available for use today. I have over 20 years of experience. My Ph.D. is in gasification and combustion. I have performed research in this area.

Second, gasification of biomass with coal is the technically best method for extracting the available energy from carbon from the biomass to produce transportation fuels and other chemical products. I repeat, it is the technically best method for extracting the energy and carbon from that biomass.

Third, this technology is ready for first-of-kind facilities in the United States, just as it is currently being applied in other nations. Except that in America engineering, ingenuity, and the will to control greenhouse gas emissions can provide a beacon to the global commons.

Let us turn our attention to the concerns about water that has been brought up. On Page 12 I present a drawing showing the demand and discharges of water for a representative coal-to-liquids plant. A large amount of water is needed, as has been stated, to produce hydrogen and to provide process cooling throughout these plants. Evaporation losses in the cooling tower can be significant. As much as 10 to 15 barrels of water per barrel of liquid product will be required unless standard operating practices are changed.

Gas to gas coolers and closed-loop heat recovery cycles can be deployed to reduce the water demand to as little as three to five barrels per barrel of liquid product. The technology exists. It is a matter of cost, benefit to tradeoff, and a will to implement these changes.

In my written testimony I will draw attention to the potential of using coal-bed methane wells-produced water to supply coal-to-liquids plants. For example, I project the possibility of using coal-bed methane water that may be produced in the Wyoming Powder River Basin to support the production of four million barrels of synthetic fuels produced over a 50-year period. The water availability may not be the barrier to start up of the first coal-to-liquids plants or those that are built and replicated thereafter. It may simply be the cost benefit tradeoffs required to reduce that water consumption. Again, American ingenuity and engineering can help.

I think I will pass by my comments on suggestions for research that could, that the Federal Government could support. I think most of my information is in the written testimony, and a lot of that has already been brought up.

In the interest of time I would like to just proceed to my conclusions. I believe the U.S. can establish greater energy independence using hybrid and electrically-powered cars, as been suggested, while assuring there is an adequate supply of diesel and jet fuels for, please understand, aircraft, shipping vessels, trains, heavy vehicles, and machinery that currently consumes a high percentage of the petroleum derived in fuels in the U.S.

A balanced portfolio of clean energy is needed inclusive of clean coal conversion to electricity, chemicals, and transportation fuels. It is important to national security and climate control that clean coal-to-liquids plants be constructed to establish the experience and infrastructure necessary to establish this industry in the U.S.

Thank you for allowing me to speak.

[The prepared statement of Dr. Boardman follows:]

PREPARED STATEMENT OF RICHARD D. BOARDMAN

Mr. Chairman and Members of the Subcommittee, I am honored to be invited to contribute to the discussion about the benefits and challenges of converting coal into liquid transportation fuels by gasification followed by catalytic transformation of the resulting syngas into synthetic diesel and other petroleum-like substitutes. This method of converting coal into synthetic fuels is often referred to as the Fischer-Tropsch process.

INTRODUCTION & BACKGROUND

By way of introduction, I am a senior consulting research and development lead for the Idaho National Laboratory (INL) where I have worked for the past 17 years. My project assignments have covered a spectrum of fundamental and applied research projects in nuclear fuel reprocessing, radioactive waste cleanup, pollutant emissions control, clean coal technology development, and gasification-based technology assessment, development, and process design. Over the past six years, my

research efforts have primarily focused on integrated gasification and combined cycle power generation, and process modeling of Fischer-Tropsch synthetic fuels plants. I am currently working with other scientists and engineers at the INL, regional universities, and private companies to develop gasification technology and associated process understanding to efficiently convert hydrogen deficient materials (i.e., coal, coke, resid, biomass, and other opportunity fuels) into clean fuels, substitute natural gas, electrical power, and chemicals such as ammonia. I am also the Lead for the INL Energy Security Initiative, aimed at increasing the Laboratory's capabilities and missions in developing **CLEAN, SECURE, ECONOMICAL,** and **SUSTAINABLE** energy solutions including the integration of the next generation of nuclear reactors to assist in the extraction and conversion of oil shale, oil sands, and coal to liquids.

I have served as an adjunct professor at the University of Idaho and Brigham Young University, providing course instruction and student advise in combustion processes, air pollutant control, and nuclear chemical engineering. I support Wyoming State government's interest to better understand clean coal conversions options, as well as private industry project development through DOE approved Work for Others and Cooperative Research and Development Agreements with the INL. I am an officer for the Idaho Academy of Sciences (IAS), just having completed a customary one-year term as the IAS President. I organized the IAS 49th Annual Conference held this past April with the theme *Energy for the Future: Environmental and Ecological Considerations.*

I provide this personal background to establish a perspective for the views that follow. While all of us here today and others across the Nation will claim an interest in protecting our environment, most will also concur that we have come to appreciate a sustained quality of life living at a comfortable temperature in decent dwellings with adequate mobility to reach our work location and other destinations in a safe, orderly, and efficient manner. We also have come to depend on an uninterrupted and diverse supply of fresh food and basic consumer commodities. The fact is that the basis for our present quality of life is realized from the development of at least three indispensable energy-related commodities: First) ammonia based fertilizers; Second) electrical power; and Third) transportation fuels, which today is primarily derived form petroleum-derived gasoline and diesel. Global demographics and the quality of life are directly correlated to these three commodities, including, but not limited to mass production and distribution of food, operation of machinery that enables mass production, and transit of these products to consumers. Remove any one of these commodities, and life as it is appreciated today, both here and in developing nations will be dramatically halted. Add all of these commodities to stable developing nations, and the standard of living will eventually approach that of the United States. Thus, we should all be concerned about the potential escalation of environmental and political consequences of increased energy demand and production around the globe.

All of us present here today are concerned with the compelling statistics regarding the imminent peaking of oil production (estimated by most to occur within 5–10 years). Adding to this concern, there is a simultaneous increasing demand for energy and transportation fuels by China, India, and many other nations. Projected population in India and China alone may increase from around 2.3 billion persons (estimated population in 2003) to over 2.8 billion in 2015. The per capita oil consumption in these two nations in 2003 was only 0.74 and 1.4 barrels per year (bbl/yr), respectively. In comparison, the per capita consumption in the United States was 25.6 bbl/yr, while it was 19.5, 15.2, and 5.3 bbl/yr in Canada, Japan, and Mexico, respectively. It is possible then, and many credible sources predict, that the global energy demand through 2050 will exceed ten times the equivalent oil reserves of the concentrated oil triangle in the Middle East, where roughly 60 percent of the remaining oil reserves are located. These combined facts underscore two potentially significant terrestrial events that are relevant to national security and global climate detriment. Clearly, I am referring to the increasing scarcity of oil and an escalation of greenhouse gases attributed to unmitigated release of carbon dioxide. These two problems should not overshadow the ongoing loss of industry in the United States, including fertilizer, glass, steel, and chemical production to foreign nations, and the impact on national security and economic prosperity when U.S. manufacturing and production further decline.

With this background in mind, I turn your attention to the purpose of my testimony today. It is my intention to address the importance of providing immediate incentives to advance coal and biomass conversion to liquid transportation fuels in an environmentally acceptable manner. I will address solutions that are being proposed and developed by the Idaho National Laboratory and industrial CRADA partners to reduce both the projected life cycle release of greenhouse causing gases and

the potential demand on water resources. This testimony will hopefully convey an understanding that the technology basis and environmental solutions for coal-to-liquids plants (CLT) are equally applicable to production of synthetic natural gas, ammonia, chemicals, hydrogen, and electrical power from coal and biomass resources. A holistic and balanced approach to resource utilization to achieve the optimum use of our natural resources will therefore be suggested. This discussion will lead to recommendations on the role of federal research in achieving these goals.

GREENHOUSE GAS EMISSIONS PROJECTIONS

I will begin my technical remarks by sharing the results of a recent technical study completed by the Idaho National Laboratory under a Cooperative Research and Development Agreement with Baard Energy, L.L.C. Baard Energy, through its project company Ohio River Clean Fuels, L.L.C. (ORCF), is developing a coal gasification Fischer-Tropsch synthetic fuels plant in Wellsville, Ohio. A process model for the project has been developed by the Idaho National Laboratory to assist Baard Energy with design and permitting activities. The model has been used to determine operating conditions to capture and sequester byproduct carbon dioxide and to study the benefits of blending biomass with coal to reduce greenhouse gas (GHG) emissions. A life cycle GHG emissions assessment based on the model results for the ORCF plant, and apportioned to the product mix of liquefied petroleum gas, naphtha, diesel fuel, and power, indicates that a 30 percent reduction in GHG emissions compared to life cycle GHG emissions for transportation fuels produced from Arabian Crude for the synthetic diesel fuel is achievable when biomass fuel is blended with the coal feeding the process and when concentrated CO_2 is separated from the syngas feed to the Fischer-Tropsch reactors and used or sequestered. When credit is also given for the sale of surplus electrical power generated by the plant (compared to the GHG emissions of the average electrical U.S. power mix), the ORCF plant will further reduce GHG emissions approaching 50 percent of the emissions from ultra-low sulfur diesels derived from crude oil. Additionally, other plant products, specifically the synthetic naphtha liquid produced by the Fischer-Tropsch process which may be used to produce additional transportation fuels or chemical feedstock such as ethylene, can also reduce GHG emissions compared to similar petroleum-derived products.

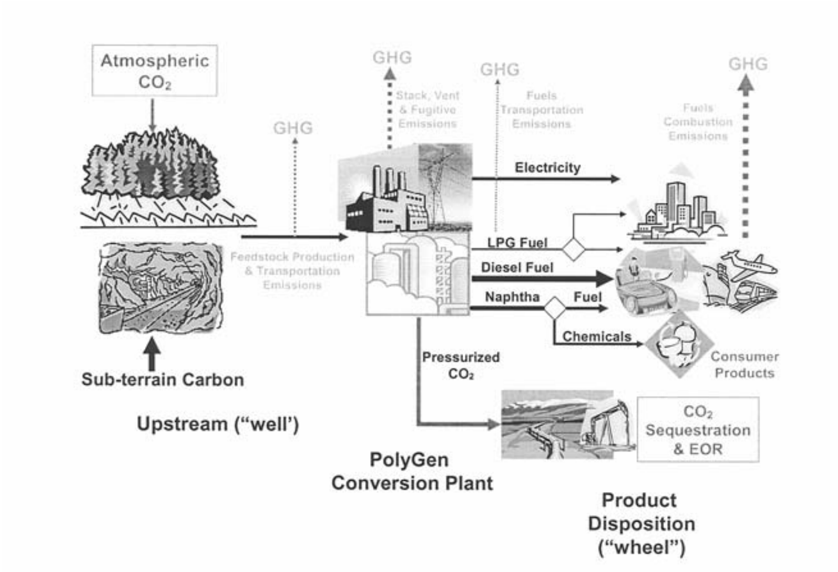
The results of the Baard Energy study are being presented in eight days at the 24th Annual International Pittsburgh Coal Conference being held on the doormat of the Sasol Secunda CTL complex in Johannesburg, South Africa. While some key findings of the INL–Baard study are provided here today, I encourage you to review this technical paper after it has been released with the Conference Proceedings.

The table below summarizes the life cycle emissions of greenhouse gases for CTL transportation fuels on the basis of the mileage attained by a standard U.S. utility sports vehicle averaging 24.4 miles per gallon when operating on petroleum diesel.

Case or Reference Data	GHG emissions* (grams equivalent CO_2 per mile driven)
Arabian Crude Fuel Product	~510
NETL CTL Plant Estimation	~938
INL-Baard Case 1. 100 wt.% Bit. Coal, no carbon capture	1050
INL-Baard Case 2. 100% Coal with CO_2 capture and sequestration	610
INL-Baard Case 3. 70 wt.% Bit. Coal, 30 wt.% biomass	801
INL-Baard Case 4. 70 wt.% Bit. Coal, 30 wt.% biomass with CO_2 Sequestration	358 (30% reduction compared to crude)
INL-Baard Case 4 with credit for carbon emissions trading for surplus electrical power sold to the utilities market	285 (46% reduction compared to crude)

*GHG emissions include CH_4 and N_2O converted to equivalent CO_2 concentrations

The INL–Baard study takes into account all greenhouse gas emissions associated with fuels and feedstock input production and transportation to the CTL plant. The study includes cases where woody biomass produced in the United States is blended with the coal in the same manner that already has been proven technically feasible in Europe at the Puertollano, Spain and the Buggenum, Netherlands integrated gasification, combined cycle (IGCC) power plants. The study accounts for all greenhouse gas emissions associated with conversion of the fuels into syngas and subsequent cleanup and conversion of the syngas into liquid fuels using the Fischer-Tropsch reaction process and associated product upgrading and refining. Next, the study takes into account the greenhouse gas emissions associated with delivery of the fuel to consumers and finally the consumption of the fuel in a standard transportation vehicle. This study emulates the work performed by the DOE National Energy Technology Laboratory (NETL), and investigations by other federal, university and private organizations to assess "well-to-wheel" greenhouse gas emissions associated with various transportation fuels. While such studies invoke specific assumptions, it should be noted that the majority of the greenhouse gas emissions are attributed to the CTL plant and end-state combustion as illustrated in the figure that follows.



This INL–Baard life cycle greenhouse gas study corroborates the findings of other organizations, but varies to the extent that the design of the CTL plant differs from the other studies. It is important to understand there can be significant variation in the CTL plant emissions depending on unit operation choices, the options selected for the integration of heat and material recycle, and the decision to co-produce electricity or other chemical products. I hereby state without reservation that greenhouse gas emissions for coal-derived transportation fuels can be reduced by at least 20 percent relative to petroleum fuels. The INL–Baard study shows that a 30 percent reduction may be possible before credit is taken for the clean power produced by the plant. When apportioned credit is taken for the green power co-produced by the plant, the GHG emissions reduction is estimated to be 46 percent as previously indicated by Baard Energy in a press conference just last May. It is also important to state that these reduced levels of GHG emissions can be accomplished using existing technologies to concentrate and remove the CO_2 produced by the process, and by blending biomass with the coal feedstock.

Some important observations of the study include the following:

1. Almost 50 percent of the carbon fed to the CTL plant can be readily captured and sequestered in an appropriate geological sink or it may be used for enhanced oil recovery.
2. Approximately 30 percent of the carbon is incorporated in the liquid and gaseous fuels produced by the plant.

3. Approximately 15 percent of the carbon is converted to electrical power that is used for the auxiliary load requirements in the plant while also producing much needed clean electrical power.
4. Sequestration of the bulk CO_2 produced and process efficiency improvements can easily reduce life cycle GHG emissions from CTL transportation fuels to a level comparable to fuels derived from crude oil.
5. Use of 30 percent biomass by weight achieves an apportioned reduction percentage of approximately 20–25 percent, depending on the choice of biomass utilized and the relative carbon content and moisture levels in the biomass.
6. The surplus electrical power produced by a CTL plant is neutral with respect to GHG emissions when 30 weight percent biomass is used in combination with CO_2 sequestration (please refer to the Pittsburgh International Coal Conference paper for a detailed explanation).

In addition to these conclusions, other environmental benefits of the combination of coal and biomass conversion to synthetic fuels using the gasification/Fischer-Tropsch process include significantly reduced emissions of sulfur and other acid rain and ozone pollutant precursors and complete control of mercury and other toxic metal emissions. Additionally, it can be shown that this manner of converting biomass to liquid fuels, specifically woody biomass as well as most herbaceous materials, is a much more efficient method of converting and utilizing the chemical potential of biomass. The GHG emissions associated with indirect conversion of biomass to liquid fuels are significantly less than ethanol fuels derived from the popular fermentation process.

Auto manufacturers in Europe and Japan are now producing hybrid cars that will operate on diesel fuel and will attain higher fuel mileage than their gasoline-electric driven counterparts. Therefore, the diesel fuels produced in the manner outlined in the INL–Baard study will further reduce greenhouse gases emitted from a hybrid vehicle. In other words, the greenhouse gas emissions are mainly due to the production of the fuels, and are not a strong function of type of fuel used in the hybrid vehicle.

FEASIBILITY OF GASIFYING BIOMASS WITH COAL

Regarding the technical feasibility of incorporating biomass with the coal feed in a coal-to-liquids plant, coal gasification plants in Europe have demonstrated the viability of operating commercial, high-pressure, entrained-flow gasifiers with blends of biomass for sustained periods of operation. While the Baard ORCF project is based on gasifier technology that has successfully operated on with biomass and coal blends, there are other options that can be used to incorporate biomass gasification into a CTL plant. One alternative is to independently inject the biomass into the gasifer while simultaneously feeding coal through a separate nozzle. A second option would be to locate a set of gasifiers designed specifically to gasify biomass along with the battery of conventional entrained-flow gasifiers used for pulverized coal. Both high-pressure fluidized-bed and fixed-bed biomass gasifiers are commercially proven and available. This option opens the possibility of using the high temperature of an entrained-flow coal gasifiers to destroy tars and oils produced at lower operating temperatures in the fluid-bed or fixed-bed biomass gasifiers.

Biomass by itself can be difficult to gasify due to its high moisture content and other physical and chemical properties. Biomass gasifiers inherently produce tars and oils that are troublesome to convert into syngas in conventional biomass gasifiers. Another problem can be the low melting point of the ash which can be difficult to manage. Hence, significant attention continues to be directed to developing efficient and reliable biomass gasifiers. However, when the biomass is blended with coal and gasified in a high temperature slagging gasifier, the issue of tar formation is eliminated. The slag produced by the biomass is readily incorporated into the higher mass of slag produced by the coal. These facts underscore the benefits of gasifying biomass with coal. It is technically the best method of converting the biomass to syngas and subsequently to synthetic fuels. Additional arguments in favor of co-gasifying biomass with coal are beyond the scope of this testimony, but can be provided by any expert in gasification and thermal conversion processes.

Biomass gasification should not be considered a barrier to current project planning that is aimed at reducing greenhouse gas emissions and other environmental impacts. However, commercialization and testing of proven and emerging biomass gasifiers, in connection with testing by DOE and industry of dry feed pumps and advance syngas cleanup technology should continue. Improvement of biomass feedstock collection, preparation, and delivery technology and infrastructure should also be supported. This work will expand the possible uses of a wider variety of biomass, and will increase our current understanding of the benefits and potential impacts

of biomass gasification on refractory life and syngas cleanup requirements, for example. In conclusion, the feasibility of using biomass with coal can be resolved with engineering, ingenuity, and the will to do so.

The fact that biomass itself can be converted to liquid fuels begs an answer to the supposition that the U.S. need not develop its coal resources to produce liquid transportation fuels. The short explanation is that resource availability and economics do not support this assumption. In order to match the current U.S. consumption of over 20 million barrels of oil per day, two-thirds of which is converted to transportation fuels, a formidable amount of biomass would be required. However, a ratio of 30 percent biomass and 70 percent coal for synthetic fuels is much more plausible. For additional information, I refer you to the 2005 "Hirsch Report" that discusses peaking of world oil production and its impacts and mitigation alternatives.[1]

The INL–Baard study of a notional 50,000 barrels per day synthetic liquids plant would use approximately 8,000 to 9,000 tons per day of woody biomass at 15 percent moisture content (harvested wood typically contains about 30–40 percent moisture). This material will need to be collected, dried, and ground to specifications meeting the gasifier feed system requirements. I cite with permission an example of a U.S. project currently under construction near Selma, Alabama that will produce dry wood pellets containing about seven percent moisture. This project, referred to as the Dixie Pellet project, will use biomass gasifiers to produce hot gas and substitute natural gas to produce pellets with minimum use of fossil-based energy. The exception will be the electricity used in the plant which will be purchased from a local utility provider. This plant, when operated at capacity, will produce upwards of 1,500 tons/day of dry wood pellets that could be readily shipped to a coal-to-liquids project. Hence, indications are that five to six comparable plants will support the biomass required for one 50,000 barrels per day CTL plant using 30 wt. percent biomass with 70 wt. percent coal. Whether the CTL plants purchase biomass collected and assembled by plants such as the Dixie Pellet Plant, or whether they implement in-line feed stock preparation is a matter of plant design choice and will depend on the region where the plant is located and the variety of biomass available. Biomass derived from switch grass, animal waste, and woody sources can all be gasified with an appropriate choice of gasification technology.

Obviously, it will not be economically viable for all plants, especially plants located in the high deserts of the upper Rocky Mountain States, to collect or transport biomass from high growth regions of the United States. Some have suggested that the overgrowth of western forests would be a reasonable source of biomass for western plants. It is likely that logistics, economics, and environmental impacts of collecting dead or diseased timber for synthetic fuels production will rule out using this potential source of biomass for these synthetic fuels projects. However projects in western states (as well as other states), may take advantage of any of the following recommendations.

1. Begin with a plant design that maximizes the concentration, separation, and capture of CO_2. Approximately 50 percent carbon capture is readily attainable.
2. Implement energy saving technology, including, but not limited to heat recovery cycles that can utilize the low grade and intermediate grade steam that is produced by the Fischer-Tropsch reactors and integrated unit operations.
3. Consider co-locating the CTL plant with other renewable energy providers such as wind power turbines to offset the GHG emissions resulting from the plant. In this manner, higher ratios of product recycle would be incorporated into the plant while using a significant portion of "green" power for the plant auxiliary loads.
4. Locate the CTL plant near the mine mouth, and where possible, in proximity of existing refinery industry to minimize the greenhouse gas emissions associated with transportation of the feedstock and plant products.
5. Select coal resources that are near the surface to minimize greenhouse gases associated with coal-bed methane releases and resource production. Western coal mines typically release significantly less CH_4 and CO_2 greenhouse gases than eastern coal mines.

[1] Robert L. Hirsch, et al., *Peaking of World Oil Production: Impacts, Mitigation & Risk Management,* February 2005, available at: *http://www.netl.doe.gov/publications/others/pdf/Oil_Peaking_NETL.pdf*

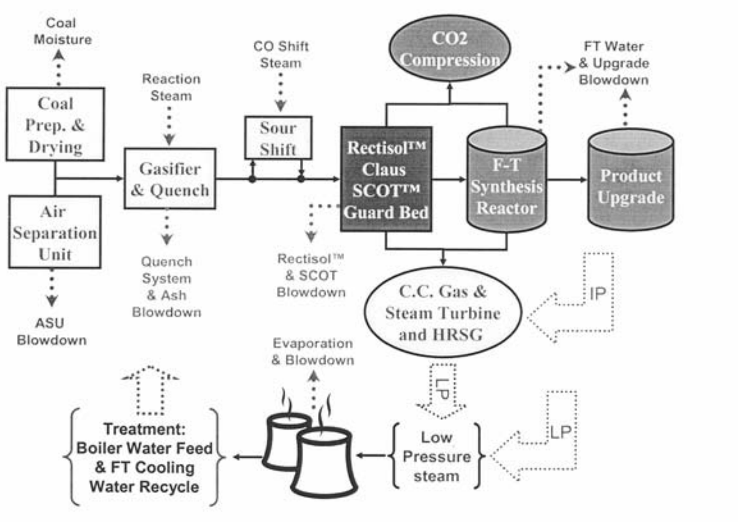
6. Consider biomass transportation costs and logistics when trains moving coal to energy importing states in the East and Southeast return with biomass from high growth biomass regions.

Expanding on the second recommendation on this list, I am personally aware of, and have technically reviewed one closed-loop heat recovery technology that is capable of recovering and converting 95 percent of the energy contained in the copious amount of low-grade and intermediate-grade steam produced by a Fischer-Tropsch plant into electrical power. These developing concepts take advantage of low boiling point fluids that can condense the steam, thus eliminating the cooling tower loads while increasing electrical power production by as much as 15–20 percent. This is an example of how impetus to improve the efficiency of a CTL plant will spur creative engineering aimed at designing more efficient and cleaner plants.

WATER RESOURCE REQUIREMENTS

Let us now turn attention to water consumption concerns associated with synthetic fuels plants. In a recent workshop sponsored by the Gasification Technologies Council, I presented data that indicated the consumption of water in a coal-to-liquids plant could approach 15 barrels of water per barrel of liquids fuels product for low moisture bituminous coal, and 12.5 barrels of water per barrel of liquid fuels for high moisture sub-bituminous coal. The basic problem is two-fold; first, coal does not contain the amount of hydrogen that is required for synthetic fuels production, and second, process cooling water and cooling tower evaporation rates in CTL plants are significant.

Approximately five times the atomic ratio of carbon to hydrogen in coal is needed to produce synthetic natural gas (CH_4) while approximately 2.5 times this ratio is needed to produce liquid fuels. Water (as steam) is used to make up the hydrogen requirements. This is currently accomplished by shifting CO and water (H_2O) to hydrogen (H_2) and CO_2. The Fischer-Tropsch process converts a portion of the syngas to water (in the form of intermediate pressure stream) while producing the liquid hydrocarbon products. The general plant water use and rejection locations and discharges are illustrated in the figure below.



In summary, process makeup water, cooling tower evaporation, and dirty process water discharges (i.e., blowdown) can be significant. Hence, water demand is a concern, especially in arid locations.

A custom-design heat recovery system for combined-cycle power generation and process water recovery, treatment, and recycle can reduce the water consumption for bituminous coal-to-liquids plants from 15 to 10.5 barrels of water per barrel of liquid hydrocarbon product. Combined use of moist biomass with coal can further reduce the process water requirement by one-half (1/2) barrel of water per barrel

of liquid product. In this case, the plant water use is approximately apportioned among the following sinks:

- 1.75 barrels of water per barrel of liquid fuels for process requirements
- 6.0 barrels of water per barrel of liquid fuels for cooling tower evaporation losses and blowdown
- 2.25 barrels of water for cooling tower evaporation losses and blowdown associated with surplus power generation

These relative figures hopefully contribute to the understanding of the water requirements for a CTL plant. Studies regarding water requirements vary widely, but are generally consistent with the plant design and reporting basis. The most important point to capture is that cooling tower losses and waste water blowdown constitute the majority of water required for a CTL plant (8.25 of 10 barrels for the INL case study). In order to reduce the water duty, gas-to-gas heat exchangers could for used for steam cooling. Alternatively, a closed-loop heat recovery system, such as that referred to previously in my testimony, would eliminate the cooling tower and water evaporation losses, while also increasing electrical power generation by 15–20 percent. Incorporation of a closed-loop heat recovery system would provide the joint benefit of reducing water use while reducing greenhouse gas emissions. Thus, the water requirement can be reduced to as little as 3–5 barrels of water per barrel of synthetic liquid product.

Another point to consider is the opportunity for CTL plants located near the coal mine to use coal-bed methane (CBM) produced water, or oil field water. For example, the Wyoming Coal Gas Commission estimates the potential water production from nearly 24,000 wells in existence in the Powder River Basin could yield upwards of 15 billion barrels of water over approximately 30 years. The water quality of a large portion of the PRB basin CBM water is adequate for direct use in a CTL plant. The salinity or hardness of the remainder of the water can be reduced with minimal water treatment, possibly comparable to the current cleanup requirements for much of the surface or well-produced waters used in power plants throughout the United States.

If two-thirds of the estimated CBM produced water in Wyoming were used for CTL plants in conjunction with advance steam cooling technology, then there would be sufficient water to produce four million barrels of synthetic fuels per year over a 50-year period.[2] This is equivalent approximately 25–30 percent of the transportation fuels currently consumed in the United States.

NEXUS OF CTL WITH NUCLEAR ENERGY

It is also worth noting is the possible nexus of coal and unconventional fuels production with nuclear energy. With the electricity produced from a nuclear reactor it is possible to produce oxygen for a coal/biomass gasifier while concurrently producing hydrogen for the Fischer-Tropsch reactor. Future class nuclear reactors will also have the capability of boosting the pressure of the low-grade and intermediate grade steam to levels amenable for electric power generation by a steam-driven electrical power turbine-generator set. Consider also the possibility of co-electrolyzing CO_2 with water inside a fuel-cell operated with power and heat produced by a nuclear reactor. In this application, the CO_2 and water would be converted to CO, H_2, and O_2—all essential inputs to coal and biomass gasification and Fischer-Tropsch synthetic fuels production. Thus, the amount of carbon incorporated in the fuel could theoretically exceed 95 percent. Other studies funded by AREVA using Powder River Basin coal as the feed and an advanced generation nuclear power plant showed that greater than 96 percent of the carbon in coal could be converted to liquid fuels.

BENEFITS OF A HOLISTIC APPROACH

The preceding discussion supports the argument for a holistic approach to energy and transportation fuel development that is protective of the environment, while giving adequate attention to sustainable and secure energy for the Nation's future. The urgency for clean energy need not come at the expense of national security. As the Nation moves forward using biomass and other renewable energy resources, and eventually with nuclear power and heat, it will be possible to again produce ammonia for fertilizer, chemical feedstock for consumer products, industrial gas for gas and steel production plants, and clean hydrogen for electrical power production (as known as FutureGen), hydrogen for sour crude and unconventional fossil fuel upgrading, and last, but not least, secure transportation fuels for the next century and

[2] (1,000,000,000 bbl-water)/(5 bbl water per bbl-fuel produced)/(50 years) = 4,000,000 bbls fuel/yr for 50 years.

beyond. This can be done *while reducing greenhouse gas emissions.* Failure to take on this leadership will only transfer this responsibility to future generations and foreign nations that will continue to produce the products demanded without probable control of greenhouse gas emissions. Failure to assume this leadership will also result in economic decline and increased national security risk. On the other hand, willingness of project developers and environmental protection organizations to accept coal conversion with biomass blending and carbon management will enable the U.S. to provide solutions to our global commons, while assuring secure, clean, efficient, and sustainable domestic energy for the future.

Other system approaches could consider the use of high pressure CO_2 slurries to transport western coal and CO_2 to CTL plants and carbon sequestration sites in the East, with a return line bringing water from the East to the arid West as practical. The reality is that the U.S. is not short on viable solutions to build a clean, and secure CTL industry. Such ideas abound within the Nation's research academic institutions and national laboratories. The key for currently developing projects is to implement proven technology with a goal of reducing greenhouse gases and minimizing water use. This recommendation is consistent with other technical experts who have previously testified before congressional committees. It is consistent with DOE and Department of Defense objectives to establish a secure domestic supply of transportation fuels while simultaneously mitigating global climate impact concerns.

I personally support efforts to convince the U.S. to conserve energy, while moving to a new fleet of hybrid cars and electrically-driven commuter cars. I support accelerated development of wind and solar energy, as well "smart" deployment of nuclear electrical power generation. I support a movement to develop biomass as a national resource, and the associated deployment of a system to improve yield, collection, preparation, and transportation of this resource to points of efficient conversion into energy and transportation fuels. However, I also believe the pending peaking of oil production, as well as diminishing domestic reserves of natural gas, in parallel with global energy demand projections and the acute need to address climate change point to the urgency for the United States to begin unprecedented efforts to begin building plants for transportation fuels from the Nation's abundant supply of coal with biomass. It is both in the interest of national security as well as global environmental protection. The example established by the United States can serve as a model for other countries to follow. This task cannot be left purely to the market place, since it is not presently the lowest cost method to produce electricity, natural gas, ammonia, chemicals, and transportation fuels. It is for these reasons that "big oil" is not currently investing in the development and construction of CTL plants in the United States. Therefore, federal incentives to move to a synthetic fuels industry are necessary for timely market entry—in a manner that is protective of the environment. Establishing necessary greenhouse gas reduction targets will impact the economics and risk of the first U.S. plants; hence, assistance in the form of loan guarantees and tax advantages will help establish this vital industry ahead of significant economic incentives.

ROLE OF FEDERAL RESEARCH

In my opinion, the role for federal research is to press forward with its existing programs to promote commercial development of *clean* and *efficient* coal-to-liquids plants. Efforts that support the characterization of sites for CO_2 sequestration should be accelerated in order to provide technically acceptable options for the first CTL plants. In addition, efforts to advance biomass gasification, particularly with coal blends, will help expand the current set of commercially available options. Ongoing efforts to improve and expand biomass feedstock collection and preparation options, as well as high-pressure injection technology, are encouraged. Additionally, federal research aimed at demonstrating emerging heat recovery options is advised. Concepts that recovery the heat from low grade stream to help reduce water consumption while improving overall plant efficiency (thus further reducing greenhouse gas emissions) should continue to be validated through appropriate technology demonstrations supported by federal research funding.

Process modeling of integrated CTL plants should also continue. These studies may include investigation of the technical feasibility of emerging heat recovery options. Process modeling can be complemented with academic research aimed at developing a deeper understanding of the fundamentals of Fischer-Tropsch reactor hydrodynamics and reaction processes. The benefit will be improved reactor designs for future plants and computational tools to help optimize operating conditions in first-of-kind CTL plants in the U.S.

A study that addresses the feasibility of collecting, treating, and using coal-bed methane produced water would have significant ramifications on the impact of es-

tablishing CTL plants in some western states. This potential benefit may also apply in eastern and southern states. The study may also consider the use of this limited water resource for biomass growth and reclamation of coal mine terrain.

Development of a national basis for estimating greenhouse gas life cycle emissions, inclusive of potential credits for co-generation of electrical power and other consumer products derived from a CTL plant is advisable. An acceptable arbiter of carbon emissions and credits for all possible energy platforms and co-generation plants will require careful and factual consideration of system interactions with the environment. The comparative INL–Baard life cycle emissions studies are considered accurate, but leave open the possibility of calculating other greenhouse gas emissions benefits associated with the non-transportation products from a CTL plant. This merely points to the interdependence of energy with other consumer products and not strictly the transportation sector. Similar consistent calculation methods should be developed for other energy conversion platforms.

Federal research covering infrastructure needs, including the capability of manufacturing and transporting gasifier and Fischer-Tropsch reactor vessels to CTL projects locations is advised. One of the most significant cost and schedule impediments to establishing the CTL industry in the U.S. is the lack of heavy vessel manufacturing capability throughout the world. In order to establish greater independence from foreign controls, the U.S. may need to re-establish this capability. A social-economic study on the buildup requirements and logistics of this critical infrastructure component is recommended.

A holistic approach to deployment of CTL plants with biomass and water resources, and nuclear assisted energy should be pursued as an out-reaching goal. Although this should not impede the first generation of CTL plants, such an outlook will help ensure optimal use of our nation's resources and environmental protection for future generations. As the Nation expands this industry beyond the first generation of CTL plants, it will become increasingly important to consider overall system performance.

CLOSING REMARKS

I recommend a balanced federal focus on renewable energy and development of the Nation's coal. Mass deployment of "smart" hybrid and electrically powered cars should be pursued in conjunction with the development of synthetic fuels from coal. These two objectives are complementary and mutually compatible. In this manner, the U.S. can establish greater energy independence, while assuring there is a proper fuel choice for aircraft, shipping vessels, trains, heavy vehicles, and machinery that currently consume a high percentage of the petroleum-derived fuels in the U.S.—namely diesel and jet fuels. The aims of environmental protection advocacy groups and the coal industry should not be viewed as being exclusive. A balanced portfolio of clean energy is needed, inclusive of coal utilization and conversion to electricity, chemicals, and transportation fuels. I believe it is possible to reverse greenhouse gas emissions when considering methods to reduce the greenhouse gas emitted from coal-derived fuels and chemicals. Incentives to encourage clean CTL projects are therefore both important and necessary.

Federal and State governments can help build the supporting infrastructure necessary to propagate the synthetic fuels industry ahead of any imminent global energy crises. Absent from my testimony today, but of significance, is substantive argument to establish domestic capability to supply the steel, manufacture the vessels, and erect these plants before they become vitally necessary in a relative short time frame. The Federal Government can focus attention on rebuilding these capabilities by working with industry and equipment fabrication shops in various regions where coal-to-liquids plants will be constructed. There is a need to continue to build liquid product and CO_2 pipelines, while providing practical and acceptable solutions for carbon management.

In conclusion, moving forward with a set of clean CTL plants today, and the research roles identified earlier, responsible infrastructure can be established to help ensure our nation's energy and political security. Workforces can be trained and engaged and economic prosperity sustained by industrial construction and plant operations on home soil. The U.S. can provide technical leadership to other nations poised to utilize coal to meet their increasing energy demands.

DISCUSSION

Chairman LAMPSON. Thank you very much. Now we will move into the question period, and each Member will have five minutes. I yield the first five minutes to myself as Chairman.

WATER CONSUMPTION WITH COAL-TO-LIQUIDS PLANTS

Dr. Boardman, let me start with you. In your written testimony you state that a coal-to-liquids plant could produce or could approach 15 barrels of water per barrel of liquid fuel product from low moisture bituminous coal and twelve and one-half barrels of water per barrel of liquid fuels for high moisture sub-bituminous coal. How does that water requirement compare to conventional petroleum-derived motor fuel production now?

Dr. BOARDMAN. I am not sure that I can give you an exact answer, but, again, these plants require hydrogen. Carbon is deficient to that hydrogen, and so you need water, at least a barrel of water to make up the hydrogen needed to formulate the synthetic fuels. The majority of the water, Mr. Chairman, is actually consumed in the cooling towers that are used to cool the intermediate and low-pressure steam. And so in that part of the plant by that evaporative process of those cooling towers you lose copious amounts of this water.

Chairman LAMPSON. Some strategies to change that?

Dr. BOARDMAN. Yes. That is where the need to upgrade the plants to these gas-to-gas heat exchangers then which would eliminate the duty on those cooling towers. Also, as we progress forward to look at these closed-cycle heat recovery loops that many are working on in the United States, that will also help.

Chairman LAMPSON. And is there a role for federal research to help insure that those strategies become effective?

Dr. BOARDMAN. Yes. In that particular area I think a demonstration of some of these closed-loop heat recovery cycles is recommended.

CO_2 EMISSIONS

Chairman LAMPSON. Okay. For both you and Dr. Bartis, you discussed the possibility of reducing CO_2 emissions when biomass is blended with the coal during the liquid fuel process, and then, and when concentrated CO_2 is separated from the syngas feed and sequestered, what are the technical challenges with combining coal and biomass in order to achieve a significant CO_2 reduction target?

Do you want to start or Dr. Bartis, you start, and then we will go to Dr. Boardman.

Mr. BARTIS. The gasification takes place at 15 atmospheres of pressure or so. So the challenge is getting biomass into that gasifier and going through that pressure change. And then once it is in the gasifier, you want to make sure that it doesn't interfere with the internal workings of a gasifier that has been designed for something else. So I think it is a pretty straightforward process that we have here. I mean, this is not science. It is technology and testing, but I think we need a few test rigs built, designed and built, and we need to make sure that this system works.

We are handling solids, and whenever you handle solids, you have tremendous uncertainties. It is very hard to scale up, so the only way to make this technology truly commercial is to test it at some scale.

Now, there is some experience in the Netherlands on using biomass for gasification, but it turns out these are very small

amounts, and they are very special forms of biomass. They are not biomass types that typically would be found in the United States.

So I think there is a real opportunity here to do something on a very short timescale.

ROLE OF THE FEDERAL GOVERNMENT

Chairman LAMPSON. Okay. So, again, is there a role for the Federal Government to plug in?

Mr. BARTIS. I think there are lots of uncertainties with regard to the future of coal-to-liquids in the United States, and I just don't see the private sector coming up with a lot of its own funds to move this technology forward. So I think there is a role for the Government.

Chairman LAMPSON. Do you want to make a quick comment, Dr. Boardman?

Dr. BOARDMAN. Well, I concur, for feed injection high pressure is certainly an issue that can be further developed and improved, springing from the experience in Europe, but I might also mention that when we talk about biomass and coal gasification, sometimes we think that has to be done in the same gasifier. It is entirely feasible to do them in two separate gasifiers. These coal-to-liquid plants will require a battery of gasifiers. So it is possible to use already existing and proven biomass gasification technology, both in Europe and developing in the U.S., to gasify the biomass and the coal in two separate reactors, combining that syngas.

But, again, I think those dry feed systems is probably the area where research focus could mainly be put.

CAN WE USE THE HYDROGEN EXTRACTED FROM THIS PROCESS?

Chairman LAMPSON. If I continue with my questions the way I am going, I am going to run out of time. So let me digress from what I intended to do and just ask a question that came up yesterday in some discussions with staff on this. And the process which I am trying to understand and I do not, I am told that a significant amount of hydrogen is separated from this, and if that is the case early in the process, why don't we just take the hydrogen and instead of taking it all the way through this entire process to make a different kind of fuel, why don't we use it when we are trying to build this infrastructure necessary to start to distribute? Can someone comment on that for me?

Dr. BOARDMAN. May I take a shot at that?

Chairman LAMPSON. Please. Yes.

Dr. BOARDMAN. Well, certainly, you know, we have looked at a hydrogen economy, and hydrogen of itself is very difficult to transport about. It is, you know, a very light molecule.

Chairman LAMPSON. Well, would it be better for us to put our money into the research to help solve that problem than the research to take this through all these different stages to get to where we are going?

Dr. BOARDMAN. I think the hydrogen economy is well in the future. I think that the coal-to-liquids plants are a bridge to that fu-

ture, and I think the liquid transportation fuels, as well as synthetic natural gas, are very convenient carriers of that hydrogen.

Chairman LAMPSON. Thank you very much.

Mr. Inglis.

COAL-TO-LIQUIDS VERSUS PETROLEUM

Mr. INGLIS. I said to the Chairman, bingo. It seems to me that is quite the question is why invest in something that really is sort of like, well, I think when we are comparing coal-to-liquids to petroleum, we are really comparing Pintos and Vegas. Anybody remember a Pinto and a Vega? Some of the staff back here is too young to remember. Well, a Vega, my family had three of them. They had aluminum blocks or something. They fell apart after awhile. They were maybe—the Vega may have been better than the Pinto or the Pinto better than the Vega, but really, when you are comparing coal-to-liquid and run it in a car, compared to petroleum, are we really talking about that kind of comparison rather than a really elegant solution that the Chairman was just talking to?

You figure a way to get that hydrogen into that car. The only emission is water out of the back of the car. Right? You don't have this, Dr. Bartis mentioned we can deal with the national security issue, and I think that is correct. It seems to me if we used our own coal, we are clearing dealing with the national security. We are not getting all the way, which is also fixing the environmental challenge.

So the thing that I found interesting about testimony from Dr.—let us see, Dr. Romm said and it will be interesting to hear Mr. Ward's response to this, that a carbon trading system would wipe out coal-to-liquids, destroy the economics of it. Is that correct?

Mr. WARD. Not in our view because, again, the thing you have to, I think you had it right with the Pinto and the Vega. You know, we are not talking about coal-to-liquids being something that competes with hydrogen that is some number of decades in the future. We are talking about reducing our dependence on imported oil with a similar thing. So I would look at it from the perspective of the Pinto, I have to build and protect the system for protecting my imported oil resources, while the Vega is something that I can do here at home while we are working on whatever vehicle we want for the future.

As far as your direct question on the carbon trading goes, the products are commodities. We are not talking about a new kind of fuel. These products will compete against the oil-derived products in an open market, and our analysis shows that as long as oil prices remain above a certain level, $50 a ton or whatever, the impact of that carbon will, the carbon tax or whatever carbon regulation scheme will come into place, will wash out in that process. So we—I don't see it as a definite at all.

Mr. INGLIS. And Dr. Freerks had a comment about reducing the risk of price fluctuations. What would you recommend by way of strategies to reduce that price fluctuation?

Dr. FREERKS. My concern is that if crude oil drops precipitously, it will wipe out the economic benefits of building CTL plants, and I think the economic value for CTL plants is in the 45 to $50 per

barrel range. So we can make those plants pay back their loans and give the investors a good return at a reasonable price for crude. But we need price stability and a collar on the lower end of that price in order to get the investors to be willing to put money into those plants.

Mr. INGLIS. Are you telling me a floor on prices, a floor on crude oil prices?

Dr. FREERKS. Yes.

Mr. INGLIS. Is that what you are talking about?

Dr. FREERKS. Just a guarantee that the prices will not drop below a certain level, which will just insure the economic viability of these plants' future, and we are not then dependent upon foreign sources of crude to fuel our economy and protect our——

COAL PRODUCTION

Mr. INGLIS. Dr. Hawkins, you had some different numbers in an MIT study that was mentioned in the charter for this hearing. You said that, MIT apparently says that switching or to replace 10 percent of the fuel consumption they say, I think it was your number, too, 10 percent. They say that it takes, it would take 250 million tons of coal per year. You said, I think, 470 million tons. They say it would require a 25 percent increase in our current coal production. You said a 43 percent. You are disagreeing with the MIT study I guess?

Mr. HAWKINS. My numbers are taken from the National Coal Council report, and they are aimed at a target of 10 percent reduction in the year 2025, forecasted oil consumption, which is larger than today's oil consumption. So you have two numbers; one, the larger amount of oil consumption in 2025, which is about the earliest that you would expect this industry to get spun up to a size where it could conceivably make that kind of a dent and using the technology efficiency numbers that the National Coal Council used. I don't know what efficiency numbers MIT used.

Mr. INGLIS. Thank you. Thanks, Mr. Chairman.

Chairman LAMPSON. Mr. McNerney, you are recognized for five minutes.

Mr. MCNERNEY. Thank you, Mr. Chairman. Thanks panel members for coming this morning. This is a set of very interesting testimony, and there is a lot of disagreement I see between the panel members.

Dr. Bartis and Mr. Hawkins both mentioned what I think is the very fundamental quandary that we are facing; how do we reduce our dependence on imported oil while reducing the production of greenhouse gases, and our national security depends on this, our economy depends on this, the environment. It is a very difficult, complicated question. So I appreciate the time and effort that you are putting into it.

It is important to be open-minded about CTL, but I have grave concerns, especially for surface mode of transportation. Air transportation may be a little bit more interesting, but for surface mode I think we have grave problems.

GREENHOUSE GAS EMISSIONS—COST AND VIABILITY

My question, the first question is Dr. Freerks, there are two issues I would like you to address; the greenhouse gas emissions, the cost and viability. In my mind I don't see any basis for what it is going to cost to sequester greenhouse gases, and also, the technical viability of that process. Is it safe? We don't know too much about that yet, so building an industry, assuming that that is going to be a good process, it is very, very risky.

The other question is something that has been brought up, water usage. How do you see that playing out in the long run? Water is going to be even more valuable than oil. It already is in some situations. So both in terms of usage and in terms of pollution, when the coal is mined.

Dr. FREERKS. Let us first start with carbon capture and sequestration. The coal-to-liquids process inherently captures CO_2 in several places in the plant. We gasify coal, and we capture the CO_2 from that gasification process. We run the synthesis gas, carbon monoxide and hydrogen, through a Fischer-Tropsch reactor, which in our case produces more CO_2 while shifting the carbon monoxide to hydrogen. And we capture CO_2 from that part, too. So we can capture CO_2 quite readily in our plants with no additional cost because the equipment is there for other reasons.

Now, the sequestration part of that is a separate question, and we have addressed that in our Natchez plant by teaming up with Denbury Pipeline, who is moving CO_2 from natural sources right now to oil fields for enhanced oil recovery. And the amount of CO_2 that we produce is equivalent to roughly one barrel of crude oil produced for every barrel of F–T produced. And although people may argue that that does not net decrease the greenhouse gas emissions because you are just trading CO_2 put into the ground for fuel brought up, it does increase our energy security, and we are going to burn that fuel anyways whether we burn it from imported crude or we make the crude here. It just changes where we are going to pay for that crude. So it is probably better to use our own domestic resources than it is to produce external resources and bring them in.

WATER USAGE

The other question you had was on what? The water use?

Mr. MCNERNEY. Water usage.

Dr. FREERKS. Okay. In the Natchez plant we have Mississippi River water for cooling, so water use is not an issue in that plant. We have looked at designs for plants that are capable of being put in dry climates like Wyoming, and they actually will not use any more water than they produce. When you produce a barrel of crude oil with the Fischer-Tropsch process, you produce a barrel of water, and that water can be condensed and recycled through the process, and you have no net usage of water. And that is an engineering design.

Mr. MCNERNEY. So you are saying that you use a barrel of water in the process and then you produce a barrel of water at the end of the process? Is that what you are saying?

Dr. FREERKS. You can design the plant such that you are net neutral on water. It is an engineering issue. It is a cost issue, but it can be done.

Mr. MCNERNEY. That seems farfetched to me.

LIMITATIONS OF DOMESTIC COAL RESOURCES

Mr. Ward, you have referred to abundant coal resources, and if we move forward with coal-to-liquid displacement of petroleum for surface transportation, what limitations do you see on the domestic coal resource? This was an issue that was brought up by one of the other panelists. What limitations are there?

Mr. WARD. There have been two studies completed in the last year, one by the Southern States Energy Board and one by the National Coal Council, but both took a hard look at the availability of coal, and both determined that our coal resources in the United States are more than adequate to accomplish this kind of a scale up and use the coal resources for transportation uses in addition to electricity generation.

CTL WASTE

Mr. MCNERNEY. We will have to study those reports. And you also talked about CTL being a clean resource, and while the end product is clean, clearly, it looks clean anyway. I didn't open it up and smell it, but I didn't want to get it on my suit. But how much waste is produced in producing a barrel of liquid, and how toxic is the waste? And what do you do with it, not even considering the carbon dioxide?

Mr. WARD. Well, I am going to defer to one of the scientists with us, but the waste products from a coal-to-liquids plant are very similar to what you would see in an oil refinery.

Dr. BOARDMAN. If you would like me to answer that.

Mr. WARD. You have got a gasification slag product, which is a solid product, which is also very similar to the coal combustion products you have from a coal-fueled power plant, the residual solids. They are non-hazard. They are classified non-hazardous waste in this country.

Dr. BOARDMAN. Having been involved in the intimate details of such a design and seeing one on the Baard Energy Project, I can comment to that. It is the ash product coming from the coal and the biomass that might be used. There will be some air emissions discharges. Those will be relatively clean because this process takes out all of the toxic metals in that coal, the mercury, arsenic, and other things, as well as a lot of the unburned hydrocarbon. So you basically are generating some power in that plant, but it is a combined cycle power, very clean on that discharge point. It does have some CO_2 in it that is opportune to remove in the future, but apart from that the water discharge also needs to be cleaned up but conventional technology exists to do that.

So on that basis it is, again, comparable to a pulverized coal-fired power plant that has to clean up its water discharges.

Chairman LAMPSON. Dr. Bartlett, five minutes.

PLUG-IN HYBRIDS

Mr. BARTLETT. Thank you very much.

There is an article recently that said that our usual 250 years projection of coal use might more appropriately be just 100 years. That is probably because at current use rates, they are just projecting from our current use, and we are really increasing our use of coal a bit over two percent a year. If, by the way, you increase the use of something just five percent a year, that doubles in 14 years, it is four times bigger in 28 years, it is eight times bigger in 42 years, and it is 16 times bigger in 56 years.

So if, in fact, we have 100 years of coal at our present rate of increase in the use of coal, if we increase its use just five percent, I think that would be a low figure if we are going to make any meaningful impact, then it is, we are going to run out of coal pretty darn quickly, aren't we?

You mentioned the evaporation of water and how much water it took, that is really double sin, isn't it? You are using precious water, and it takes a lot of energy to do that. You are wasting a lot of heat doing that. When the President said we were hooked on oil, he was exactly right. We are so hooked on oil that we become irrational when we are talking about alterative energy uses.

You know, we were talking about hydrogen. Why don't we just use the hydrogen? Well, you always use more energy producing hydrogen than you get out of it. Why wouldn't you just go back to the original energy source and use that? If you are talking about using coal, why don't you just burn the coal? There is no better way to get energy out of almost any product than simply to burn it. And if you are doing that where you can use the excess heat instead of stupidly evaporating precious water, then you have a double increase in the efficiency.

Am I wrong? Doesn't it make any—by the way, and if you want to get a lot of duration from your plug-in hybrid, instead of stopping to refuel your car, simply stop to switch batteries. And you can now drive an infinite distance with a plug-in hybrid, can you not?

If I am not wrong in all of this, does it make any sense to talk about coal-to-liquids? Why don't we just burn the coal and produce electricity and use plug-in hybrids?

Mr. HAWKINS. Well, I would agree 100 percent with that. I mean, I think, you know, electric motors are very efficient, so if you can generate electricity, you can use it very efficiently, and I think plug-in hybrids are the vehicle of the future. I think there is no question that if you take the coal and burn it in a gasification plant and capture the carbon and store it, you would actually have carbon-free electricity. So you would be running your car on carbon-free electricity. If you do CTL, if you do liquid coal with carbon capture and storage, you are still running your car on diesel fuel. You have not solved the global warming problem at all, but you have spent a bundle of money to get you nowhere.

So I couldn't agree with you more.

Dr. BOARDMAN. Except that when you burn that coal in those power plants, you need the same water to cool that steam that you make. The process——

Mr. BARTLETT. I would use that for district heat. All over the world they place their power production plants where there are people so that they can use the excess heat for what is called district heating. In the summertime you can simply use an ammonia cycle, refrigeration and cool your homes with this excess heat. What we do is really dumb, and we need to stop doing it, do we not?

Dr. BOARDMAN. Yes, and that same steam, though, could be taken off that coal-to-liquids plant and used the same way. It is the exact same steam, it is the exact same quality of heat.

Dr. HAWKINS. If I could just add a word about the elephant in the room and that is energy efficiency, this is the long pole in the tent if you are worried about oil dependence and global warming. We can back out more oil with smarter cars, smarter transportation systems. We can back out more global warming emissions with that, and we can give Americans increased choice, vehicles—people don't buy vehicles because they burn lots of gasoline. They buy them for the services they provide, and if we have intelligent policies that are designed to deliver vehicles that people want to drive, we don't need price supports for minimum prices of oil. Those vehicles are going to provide value to American consumers whatever the price of oil is.

Mr. WARD. I would just agree. I would agree entirely that plug-in hybrid vehicles are a place we need to go. The energy efficiency is a place we need to go. Coal-to-liquids is a bridge technology. It is not the ultimate technology. The problem with plug-in hybrid vehicles is we have got to make millions of them and convince people to buy them and use them. There are no plug-in hybrid airplanes, there are no plug-in hybrid locomotives, there are no plug-in hybrid big yellow machines that build things and long-haul trucks and those kind of things. We will continue to use liquid fuels for those types of things.

And one other clarification on the brief discussion on price supports for deployment of coal-to-liquids facilities, I don't think anyone in the industry is looking for that as a permanent solution. When we talk about commercialization incentives, we have a commercialization gap where we need to convince Wall Street that the first few of these plants can be built. So when you are looking at some sort of a mechanism to insure against price volatility in oil markets, you are only looking at that for the limited purpose of the first few coal-to-liquids plants so that you can get this industry kick started. And after that, let the industry compete against oil resources and others to fill that continuing demand we are going to have for liquid fuels while we wait for efficiency and plug-in hybrids to take hold.

Mr. BARTLETT. What you are saying about trucks and trains and airplanes is, particularly for airplanes is exactly true. They have got to have a liquid fuel. But a large part of the liquid fuels we use are in automobiles, and we can do something about that, can we not?

Thank you, Mr. Chairman.

Chairman LAMPSON. Thank you, Dr. Bartlett.

And now, Mr. Costello, five minutes.

Mr. COSTELLO. Mr. Chairman, thank you, and thank you for calling this hearing today.

RUNNING AIRCRAFT ENGINES ON COAL-TO-LIQUIDS

Mr. Ward, I appreciate you making the comment that there are airplanes and locomotives and other road-building equipment and other vehicles that have to run on liquid fuel. Both you and Dr. Freerks made the point that the Department of Defense has been a leader in moving to clean coal technology and also to coal-to-liquids. And there has been some discussion, I think, and some skeptics in the past saying, do you have to modify aircraft engines in order to run them on coal-to-liquids.

And Mr. Ward, I think I heard you say earlier that one is that CTL is not a new kind of fuel, and two, is that you do not have to modify existing engines to run them on CTL. Is that correct?

Mr. WARD. That is correct. You are making gasoline, diesel fuel, jet fuel. Those fuels can be used directly, they can be blended with petroleum-derived fuels, they can be distributed in existing pipelines and service stations. You know, this is—and that is no small issue. When you look at new types of fuels coming into play for the United States, you are also going to not only build the vehicles that run on those fuels, you are going to have to build the delivery systems for getting those fuels to market. Ask anyone who tries to drive E–85 in lots of states in this country, you know, where they can find those things.

One of the advantages to CTL as a bridge technology is we can put it into the existing pipelines, the existing vehicles, and reduce our dependence on imported oil right now.

Mr. COSTELLO. So for those who have questioned do you have to modify, does DOD have to modify the engines, they do not? Jet Blue and some of the other airlines are looking at CTL. Dr. Freerks, it looks like you want to make a comment here.

Dr. FREERKS. I have been involved with the development of the F–T fuel with the Department of Defense for about eight years, and the only concern that they really have is that they have not seen this fuel in their engines before, so they are testing to make sure that it does work. And so far all the tests show that there is no modification needed, other than that you can get more efficiency out of the fuel if you design the engine to actually run on that fuel. We can run it on the existing engines, but we can actually do better, and even NASA is looking at designing spacecraft to run on the F–T fuels because it provides a cleaner way to get into space than many of the other alternative fuels that they have been using.

So there are many advantages to this fuel. It is not only just a replacement for conventional fuels. It is an enabling fuel for both the turban engine and the diesel combustion engine where we can design the engines to be both more efficient and lower polluting because the fuel itself burns so much cleaner than conventional fuels which contain aromatics and sulfur.

Mr. COSTELLO. And it is my understanding that the Department of Defense, the Air Force in particular, has just certified a CTL blend to be used for the B–52?

Dr. FREERKS. Correct.

Mr. COSTELLO. And that just took place just a few weeks ago. Is that correct?

Dr. FREERKS. Correct.

CARBON SEQUESTRATION

Mr. COSTELLO. Mr. Hawkins, my understanding from your testimony is that you indicate that carbon sequestration makes sense for coal electricity generation but not for CTL. I wonder what you believe are the appropriate federal initiatives for developing the sequestration used for electricity production.

Mr. HAWKINS. Thank you, Mr. Costello. Actually, we believe that carbon sequestration or carbon capture and storage makes sense for any use of coal. What we question is using coal to make liquid fuels. We think that a better way to back out oil, if you are going to use coal, is to make electricity with that coal and then use it to make plug-in hybrid vehicles. We think that can deliver more barrels of oil per ton of coal with many fewer greenhouse gas emissions.

So instead of, you raised the aircraft issues, we need to look at this as an overall resource, and efficiency driven through plug-in hybrids can free up barrels of oil that then can be available for other uses such as aircraft.

So instead of spending lots of money to produce a new fuel for the Air Force, why not look at the U.S. Postal Service, have that fleet converted to plug-in hybrid vehicles, why doesn't FedEx look at converting its ground fleet to plug-in hybrid vehicles, and free up all or a part of the needs for the aircraft that need it.

Mr. COSTELLO. Dr. Boardman, do you have a response to Mr. Hawkins' statement?

REASONS TO START INVESTING IN COAL-TO-LIQUIDS

Dr. BOARDMAN. Thank you. I do. I will maybe add a new perspective here. When you look at the oil reserves to the production rates, you can look at British petroleum statistics published two years ago that indicated all of North America, if we continue at the rate of production, we will deplete those reserves within ten years. And so that means that we have got to look towards, when we are looking at all of the transportation vehicles and the heavy vehicles, our demand for that oil, if that oil depletes and national security risks go up correspondingly, we need to have an ability to generate that fuel in terms of national security.

And I think it is important for us to begin to establish that infrastructure now to be able to do coal-to-liquids because it does take time to do that. It takes time to build that, it takes heavy equipment and vessels. We don't have that capability nor that experience.

So the first few plants could establish that capability so when those declining reserves do eventually meet up to us, we are prepared to have an alternative for that liquid fuel.

Mr. COSTELLO. I thank you, and I thank you, Mr. Chairman.

Chairman LAMPSON. Thank you, Mr. Costello.

Mr. Hall, five minutes.

Mr. HALL. Mr. Chairman, thank you.

SHOULD CARBONS BE TAXED?

I have listened here and read some of your testimony. I go back to the reason we are here and what we are doing here and the major duty of a member of Congress, probably one of the major duties is to prevent a war. And right now today the major war I see by some of you on the panel there is a war against energy. You are knocking fossil fuels. You are knocking coal.

I guess to Dr. Hawkins and Dr. Romm, I would have to say that I just disagree with you. You are both pushing the fear of global warming, yet you don't have any answer for the cost of it. I just would like to ask Dr. Hawkins if you and the NRDC and Dr. Romm, if you and the Center for Energy and Climate Solutions, and I think this follows the question Dr.—Congressman McNerney was asking about, I guess I would ask Dr. Romm, do you really believe that you ought to tax carbons? Is that your, isn't that your testimony?

Dr. ROMM. No. Well, I would prefer a cap and trade system.

PRICE OF CO_2

Mr. HALL. Well, yeah. You would prefer to explain it away. Let me read it to you. I think you said, "Instead of promoting liquid coal, Congress must address the climate problem by establishing a cap on emissions that creates a price for carbon dioxide." What do you mean by that? If that is not a tax.

Dr. ROMM. Well, taxes go to the Government, and in a cap and trade system the revenue is, typically goes, you know, is circulated in the economy to find the lowest price for avoiding carbon dioxide emissions. So——

Mr. HALL. Yeah, but there is a bump in the road there and either way you go it runs the price of gasoline up. Now, please pick that up and explain it. Be practical with me, not theoretical.

Dr. ROMM. Sure. Let us be clear. There is no question that if you put a cap on emissions, carbon dioxide will have a price. But you have all these panelists here who are telling you that they are going to capture carbon dioxide from the coal-to-liquids process and bury it. Well, they won't spend a penny doing that unless there is a price for carbon dioxide that gives them a reward for that.

Now, I think what Dr. Hawkins and I would say is that if you combine energy efficiency with a switch to cleaner fuels, you have the possibility that the fuels may cost more but because you are using them more efficiently, your energy bill won't go up. And when I was at the Department of Energy we did a study with five national laboratories which showed that you could substantially reduce the greenhouse gas emissions of the United States of America without increasing the Nation's Energy Bill. And that is what our goal is, but there is no question that the price of carbon-intensive fuels has to go up. If the price of carbon-intensive fuels doesn't go up, why would anybody use less of them?

So, yes, we are in, you know, I am certainly in the camp that global warming and, you know, this is a Science and Technology Committee, and the scientists of the world have spoken earlier this year in the Inter-Governmental Panel on climate change——

Mr. HALL. Why do you express all your fears about global warming, though, and you never set forth a way to pay for it? Now, you, yourself, know that China is not going to do anything but increase the intensity of the damage to the air, and yet take all of our jobs over there, and they are not going to pay 15 cents to help our companies, our energy companies set forth energy to use at a decent figure. Neither is Russia, neither is Mexico, neither is India. I can go on down the road.

WHY NOT COAL-TO-LIQUID TO HELP ADDRESS GLOBAL WARMING?

Why would you set forth the great fear of global warming right now and not be pushing for technology like coal-to-liquid, like we have suggested here and use the abundance of coal that we have in this country to offset the fear of terrorists that threaten us? And it is a national security issue.

Dr. ROMM. Well, I am a big fan of reducing oil consumption. I wrote an article entitled, "Mid East Oil Forever." I think it is just important to understand that there is no point in addressing the energy security problem in a way that makes it harder to solve the global warming problem. I don't think there is any question that the scientific consensus on global warming is clear. We have to reduce emissions, and I think there are a lot of bills before Congress that would do just that. Coal-to-liquids does not address the global warming problem.

Mr. HALL. In any way?

Dr. ROMM. In any way whatsoever, no, because you are left with diesel fuel. Even if you cap——

Mr. HALL. Global warming. Oh, no. I agree with you on that.

Dr. ROMM. Okay. Then we are in agreement.

Mr. HALL. No. We are in great disagreement.

IS ENERGY SECURITY IMPORTANT?

Let me ask you and, let me ask Dr. Hawkins how he and NRDC feels and you, Dr. Romm, how the Center for Energy and Climate Solutions feel. Let me ask you a simple question. It doesn't mean to be an insulting question, because I know your answer is going to be yes. Do you believe energy security is important? Your answer is yes, isn't it? For both of you.

Mr. HAWKINS. Yes, of course.

Mr. HALL. So if using carbon capture and storage technology can give CTL a better life, a better life cycle, greenhouse gas profile than imported petroleum and a much better performance in the area of criteria pollutants, why wouldn't the NRDC support this, and why wouldn't the Center for Energy and Climate Solutions support that?

Mr. HAWKINS. The question, Mr. Hall, is not whether we support backing out oil with domestic resources. We do. What we are trying to urge this committee to look at is what is the best way to do this. We have raised a number of questions about why we think coal-to-liquids is not the best way to back out oil, it is not the best way to use coal to back out oil. These are questions that if you don't look hard at them, you are going to make mistakes, and those mis-

takes are going to interfere with the objective of getting energy security, and they are going to hit American taxpayers with bigger bills than they need to pay.

Those are the questions we are asking you to take a hard look at.

SHOULD WE INCREASE DOMESTIC OIL PRODUCTION?

Mr. HALL. Okay. If you are opposed to CTL, are you supporting more domestic production of oil then in order to help our national security and decrease our dependence on foreign oil?

Mr. HAWKINS. Well——

Mr. HALL. It is all fossil fuels, isn't it?

Mr. HAWKINS.—we have supported enhanced oil recovery because we do think that it is better to get additional barrels of oil out of already producing fields than it is to go into either unsecure areas of the world or go into pristine areas so——

Mr. HALL. Not drilling on Anwar and in the Gulf and offshore Florida?

Mr. HAWKINS. We think there are——

Mr. HALL. Do you recommend that?

Mr. HAWKINS.—a few places——

Mr. HALL. Yes or no? Do you recommend that, sir?

Mr. HAWKINS. We do not recommend drilling in the Arctic National Wildlife Refuge (ANWR). We oppose that. We do support drilling in the Gulf of Mexico where existing production is doing just fine, thank you, and we support a wide range, which is outlined in my testimony, of producing resources both U.S. biofuels resources, as well as, as I will repeat it again, efficiency can deliver more barrels of oil equivalent than any other tool in the toolbox.

And I would just state American consumers don't value barrels of oil. They value mobility, and if you can deliver that mobility with smarter cars that use fewer barrels of oil, then we are better off from an energy security standpoint, and we are better off from the standpoint of our wallets.

CONSTRUCTION OF POWER PLANTS

Mr. HALL. Last question. You advocate the use of plug-in hybrids. Do you therefore support the construction of a new coal-fired electric generation plant? I support nuclear powered electric generation plants. Do you support those? They add much needed generation to the grid.

Mr. HAWKINS. We think that new power plants should be designed to be the cleanest possible power plants. We are not picking technologies for new electric power plants. We just did a research report with the Electric Power Research Institute. We will need additional electric power capacity. We think we can do a lot more on renewable, wind and solar electric sources, and we are really pleased that the State of Texas is doing such a great job on wind-powered electricity. It is growing faster than any other source of electricity in Texas, and your state is a real leader in that area.

MORE ON DOMESTIC OIL PRODUCTION

Mr. HALL. Yeah. We are going about two percent of the energy. That is a big deal. Actually, ANWR, when you oppose ANWR, I guess it is because it is too pristine, and you want to save it and not damage little ANWR. It is just 19 million acres up there, and the bill calls for drilling on 2,000 acres, and it is equivalent—I will be practical with you and not scientific.

It is equivalent to saying if you take a football field, and you lay a dollar bill down in the end zone, you ruin the whole field. That is outrageous, and you know it.

I yield back my time.

Chairman LAMPSON. Mr. Wilson, five minutes.

CTL AS A BRIDGING TECHNOLOGY

Mr. WILSON. Thank you, Mr. Chairman. Gentlemen, thank you for being here today.

I have a special interest in this because as Dr. Boardman talked, the proposed Baard Energy Project would be in my district, where we also, Mr. Hawkins, we made lots of electricity along that Ohio River corridor in Ohio from Youngstown down to Cincinnati.

What we are trying to do is to find alternate ways to be able to make ourselves less dependent on foreign oil, and I believe in, not only because of the fact that we have the proper things to bring it together in our district, we also have the need in our country. And to know that this fuel can be burned as clean or cleaner than what we are burning and we are not paying for it to a foreign source, I think is very important.

One of the things that Mr. Ward talked about that I thought was extremely important for everyone to understand and conceptualize about this is that the CTL is actually a bridge to technology, and I wanted to ask you, Mr. Ward, if you would continue on that, expand on it, because I think it would answer some of the questions where folks were saying that we only have coal for 100 years. Well, 100 years is a long time.

But if you would, if you would talk on that as to what really is the effect of CTL.

Mr. WARD. Well, and, again, I think it is important to remember that we are trying to deal with two issues at the same time here; one being an energy security issue and the other one being a climate change issue. And they are both crucially important, and I think some of the tension in this debate comes when we try to put one over the top of the other.

What we are talking about with coal-to-liquids is using a domestic resource that we have to replace a resource that exacts a tremendous cost on our nation and our economy to protect the access to it in other parts of the world, largely from places where people don't necessarily like us. And so it is to take nothing away from the need to do more for energy efficiency, to do more for new types of vehicles. You know, the hydrogen economy, if we can ever get to that would be a wonderful place to be, but the reality is our production and refining base today is at its maximum level. Our refining facilities are located in places that are vulnerable to terrorist attacks and to natural disasters like hurricanes. We need to do

more to use the resources we have and expand and diversify our resource base for producing the fuels for the vehicles we drive today.

Mr. WILSON. And I think it is going to take, and please, anyone of the panel, if you will, please disagree with me if you do, but I think it is going to take the implementation of all these things, not just coal-to-liquid, not just wind, not just solar panels, but all of them, and the sooner we realize that and begin moving in that direction, I think the better off we are going to be.

CTL SUCCESS IN OTHER COUNTRIES

One of the points that I would want to ask to the panel is if coal-to-liquid is not the right way to go, why are so many other countries doing it and some becoming very successful with it? Does anyone have any comment on that?

Mr. WARD. Well, let me just take a quick one and point out, for instance, China is a country that attracts a lot of our interest. China faces many of the same dynamics that we do. They are dependent on foreign sources of oil. In fact, they are dependent on the same foreign sources of oil that we are, and they are making some critical decisions right now as to what they need to do. They can invest billions of dollars to build pipeline capacity to bring more foreign oil from the coasts to their interior where the cities are growing, or they can invest those billions of dollars in developing the coal resources that they have in the interior for making liquid fuels from their own resources. They are, in fact, investing the billions to do more with the resources they have.

I think that is, you know, the Philippines, India, a number of the growing Asian countries are making similar types of decisions, and it is easier for them to do it because the Government has a more direct role in building those first plants. The problem we face here in the United States is that we go to Wall Street and ask for the money, and until we get the first few plants built, there is a tremendous resistance from the private capital markets. Everybody wants to be the first person to build the fifth plant.

Mr. WILSON. Have we not, Mr. Chairman, have we not always in America, though, the thing that has made us above and better than most others is the fact that we do provide the technology, and we are able to move forward with the challenges we have because we are willing to take the risks and to do what is responsible.

Mr. WARD. Well, we are providing the technology that the Chinese are using——

Mr. WILSON. Exactly.

Mr. WARD.—to develop their CTL resources. So——

Mr. WILSON. Yes. Mr. Hawkins.

Mr. HAWKINS. If I could comment. Again, the debate here is not about providing incentives for technologies to get the job done. The question is why pick a fuel and why pick a process when you are providing those incentives? Why not focus on the objective? If the objective is to back out oil, then give incentives that are open to all comers for processes that back out oil. If the objective, as we believe it needs to be, is to cut global warming emissions, then provide incentives for technologies that do a better job of that. Focus on the objectives. Don't try to pick the technology or fuel winner.

INVESTING IN CTL

Dr. ROMM. If I could add two points. One is China appears to be scaling back their effort on CTL, and I posted on my blog, climateprogress.org, a couple of articles that go to that very point. So I think it is important to understand that CTL is not taking over the planet.

I think the other important thing to understand is we have $70 a barrel oil. We do not have any CTL plants in this country. Now, people tell you, we could spend money to solve the water problem, make the plants more expensive. We could spend money to capture the carbon. No one is building these plants because they cost $5 billion for 80,000 barrels a day. They are phenomenally expensive plants. They are not profitable at current prices of oil. They are going to be infinitely less profitable if you try to deal with their water and their CO_2.

So it doesn't make a lot of sense for the Government to push CTL down the throats of consumers. They are just, they don't make a lot of sense economically or environmentally.

Mr. WILSON. If I could comment on that, Mr. Chairman, I think there are two things in play there. Number one, why are we looking for coal-to-liquid? It is simply because we have an abundance of coal.

And secondly, I believe it is very important to realize that this technology is something that is going to, if we are paying $70 a barrel now, who is to say we are not paying 170 a year from now? And so what this does if we get these plants up and going, it gives us some balance in which we need badly right now. Mr. Ward.

Mr. BARTIS. Can I comment? I am a little concerned because what I hear is a lot of second guessing of the marketplace here and what works and what doesn't work. The fact is is that we have a technology. It is one of the few choices that we have that is ready now. It is coal-to-liquids with Fischer-Tropsch. The problem with that technology is that we have got a concern with global warming, and we have not proven that we can sequester the carbon dioxide emissions. That is a fact.

That fact says that we should not be putting together any incentive that promotes a large coal-to-liquids industry. It doesn't mean that we shouldn't invest small amounts of money to get some early experience, and there is a big difference between the Government trying to pick winners, rather than looking at coal-to-liquids first, as insurance, a small insurance policy.

The other thing I wanted to say is that I think it is very important to endorse what David Hawkins has said, that we focus on objectives and not on technologies. There is too much willingness among all parties it seems to me to try to pick this particular technology or that technology. The true objectives are, you know, import less oil, use less oil, and put out fewer emissions of CO_2.

And addressing one doesn't mean you are going to fix the other one. For example, we know that if we pass legislation that puts a premium on carbon emissions adequate to sequester emissions for electricity production, which is about $30 I believe, a ton of CO_2 according to the MIT study, that legislation is only going to raise the price of gasoline 35 cents a gallon.

This increase in the price of gasoline is just not enough to cause anyone to use less petroleum. So we need to think of disincentives or incentives, I prefer disincentives because they encourage efficiency in conservation, but we need to think of broad-based incentives and disincentives for using less petroleum and for reducing carbon dioxide emissions. That is the real key here.

Mr. WILSON. And I, if I may, Mr. Chairman, I think that is wonderful in an ideal world, but we are in a real world, and it is a situation where we are going to have to do something with our energy dependence, and we need to be moving on it now.

CTL EMISSIONS

Thank you, Mr. Chairman.

Chairman LAMPSON. Mr. Hill, five minutes.

Mr. HILL. Thank you, Mr. Chairman. Gentleman, I am not a member of this committee, but I am very interested in this whole issue, because I am from Indiana, which produces a lot of coal.

One of the things that I have learned in my years in Congress it is very hard to determine what the facts are in this city, and I have been listening to you for an hour now, and I still don't know what the facts are. So maybe we can clear up some of these things.

Mr. Ward, you said that coal-to-liquids is cleaner than the way we produce gasoline today from oil.

Mr. WARD. Yes, sir. The fuels that result from a CTL process are cleaner than the fuels that come from a traditional——

Mr. HILL. Okay.

Mr. WARD.—petroleum refinery.

Mr. HILL. Dr. Bartis, you said coal-to-liquids will produce 20 percent greater carbon emissions than oil.

Dr. BARTIS. They will produce much more than 20 percent.

Mr. HILL. According to the Argonne National Labs. Who is right here? Are you right, or is Mr. Ward right?

Dr. BARTIS. Well, no. There are two different issues.

Mr. HILL. Okay.

Dr. BARTIS. We are talking about two different things. One is the performance of the fuel after it is produced. The other issue is what of the greenhouse gas emissions in producing the fuel. If you look at a total fuel cycle basis, our calculations, and we have been very careful with this at RAND, our calculations show about 2.2 times as much as conventional petroleum. That is with nothing, not doing any carbon management at all. Just putting all the emissions into the atmosphere.

Mr. HILL. So, Mr. Ward, how do you respond to that?

Mr. WARD. Two ways. Number one, we need to separate the pollutants in fuel—sulfur, NO_X, particulates, the things that make people sick—from the greenhouse gas, which is a climate change issue. On the pollutants issue there is no question that the CTL fuels are much cleaner than the petroleum fuels that they are replacing.

On the greenhouse gas climate change issue, if you capture and sequester the carbon during the manufacturing process, you can make those CTL fuels on a life cycle basis be no worse than the petroleum that they are replacing.

Mr. HILL. Okay. So someone said that the technology as it relates to carbon sequestration is not here yet.

Mr. WARD. I would disagree with that, sir. The largest coal gasification plant in the country is in North Dakota, Dakota Gasification. It is 30 miles down the road from a coal-to-liquids plant we are looking at building. They capture and sequester their carbon for enhanced oil recovery. All of the coal-to-liquids developers I work with in the United States are planning to capture their CO_2 and sell it for the purposes of enhanced oil recovery.

You know, as we look at needing to move to carbon capture and storage for the electricity generation sector, I think we would be missing an opportunity. Here is the CTL industry that is willing to embrace and deploy carbon capture and storage technologies on a large scale right now, these are the demonstration projects where we are going to learn the things we need to know so that we can go back and retrofit carbon capture and storage onto our existing base of electricity generation that produces 50 percent of the power in this country.

COAL SUPPLY

Mr. HILL. Okay. So let me switch then to what Congressman Bartlett has said. Are we going to run out of coal soon if we increase production by five percent?

Mr. WARD. I do not believe we are. There is some noise on some newspaper article that appeared recently that was looking at known pieces. One of the things about coal that is similar to what it is about oil is you need to look at what these surveys are based on. Are the surveys based on the exploration that has identified the fields that are fully characterized, or are they based on what we know is out there and haven't gone looking for yet because there is no reason to. The studies I referred to earlier by the National Coal Council and the Southern States Energy Board have both identified more than ample coal reserves here in the country to support both electricity generation and transportation fuels.

MORE ON INVESTING IN CTL

Mr. HILL. Well, then why isn't this happening, Mr. Ward? I mean——

Mr. WARD. Well——

Mr. HILL.—if it is a no-brainer, why is it not happening?

Mr. WARD.—it will happen, and my position is that you will see a coal-to-liquids industry in this country. The question is how fast. The $70 oil price issue came up a minute ago. If my coal-to-liquids plant was running today in a $70 a barrel oil environment, I would be making good money with that facility. The question is when I go to Wall Street and say, please loan me $3 billion to build this plant, look at how good it is at $70 oil, they say, well, what is the oil price going to be in five years when you are paying back the loan after you build this?

Mr. HILL. So what should we do?

Mr. WARD. What we should do on the commercialization side is put in place a limited number of deployment incentives to take some of that oil volatility price risk, and there is two or three dif-

ferent proposals floating around on the Hill now that could do that. But for the first two or three plants or four or five, pick a number, plants, alleviate that oil price volatility factor so you can get those plants running. Then when you go to build the fourth and fifth plant, the people on Wall Street have something to look at, you have got a facility working.

You know, we will get a coal-to-liquids industry, you know, oil keeps going up, it gets to $100, $120 a barrel, people are going to start building these things anyway. You can let it go that way, but that does nothing to address the energy security issue of reducing your dependence on foreign oil before we face another crisis.

Mr. HILL. My red light is on. I have got like 100 more questions, Mr. Chairman, but I will let it go at that. Thank you.

Chairman LAMPSON. Mr. Matheson, you are recognized.

MORE ON CTL EMISSIONS

Mr. MATHESON. Well, thank you, Mr. Chairman. Mr. Ward, I wanted to ask you a question first. What do you feel is an appropriate level of environment performance for CTL facilities that should be met in order to achieve some kind of federal financial support?

Mr. WARD. I believe that the reason for pursuing coal-to-liquids is as a bridge strategy to help us with energy security issues while we develop the fuels and the strategies of the future. Therefore, I believe if a coal-to-liquids facility can produce a fuel that is cleaner than the petroleum fuel that it replaces from a pollutant standard, and is better than the petroleum fuel it replaces from a life cycle greenhouse gas standard, that should qualify for deployment-type incentives to get these plants built.

After that, these plants are going to be subject to the same regulations or regulatory regimes, whether it is a carbon tax or cap and trade system or whatever this Congress ultimately enacts to meet our greater goals of dealing with climate change——

Mr. MATHESON. Uh-huh.

Mr. WARD.—these plants will also be subject to future reductions to meet that system. And we will do those things through some of the technologies that have been discussed today like biomass firing and other technologies that are out there.

But to qualify for deployment incentives, if what we are trying to do is improve our, if what we are trying to do is improve our energy security, what is wrong with the standard that says as long as you are not going backwards, you qualify.

CTL COMMERCIAL APPLICATION

Mr. MATHESON. Let me also ask you a question, we have heard a lot in the context of coal-to-liquids about using biomass in connection with the coal for making liquid transportation fuels. Where is this technology in terms of its opportunity for commercial application now?

Mr. WARD. And that is really an important question for this committee where you are looking at where research dollars should be spent. Coal-to-liquids with carbon capture and storage for enhanced oil recovery is something we can do today. There is commercially-

available technologies, there are commercially-financeable technologies if we can deal with oil price risks.

The biomass coal gasification, biomass co-firing, that is earlier in the scale. That is back where we need to do demonstration projects. There is probably some more basic research that needs to be done. Those are areas where we should be spending research dollars, not deployment dollars in order to develop that technology so that it will be useful in making future environmental improvements down the road.

Mr. MATHESON. And what are the environmental benefits of that technology combining the two?

Mr. WARD. Well, when you combine the two, when you do carbon capture and storage and utilize biomass strategies, you can now go from a fuel that is as good as or a little better than the petroleum you are replacing to having a liquid fuel that is significantly better than the petroleum fuel that you are replacing.

Mr. MATHESON. And just maybe just to clarify what you said, because the Science Committee has jurisdiction over research funding. You are suggesting that for this committee that is an appropriate thing to take a look at?

Mr. WARD. Exactly. And my testimony outlined three areas that I think are most appropriate for research dollars in this area, biomass being one of them, doing more complete work on setting standards for life cycle assessments for comparing these technologies to other fossil fuels is a second one, and then continuing to broaden the options and knowledge of carbon sequestration activities outside of enhanced oil recovery is the third.

Mr. MATHESON. Okay. I appreciate that. And I am sorry I was not here at the start of the hearing, and I wanted to welcome Mr. Ward, who is from Utah. I would have introduced you if I was here at the start of the hearing, but I didn't make it in time.

Mr. WARD. That is okay. You would have said something disreputable.

CARBON CAPTURE AND SEQUESTRATION

Mr. MATHESON. One, just one last question I will throw out to any witness on the Committee in terms of the carbon capture and storage issue. It seems to me that these are, you know, CTL and CCS are both sort of in play right now. Can anyone talk about—give the Science Committee direction on the difference between the different available forms of carbon capture and sequestration and the types of research that this committee ought to encourage to help enhance policy support for different types of carbon capture sequestration?

That is for anybody who wants to answer that.

Dr. BARTIS. Carbon capture and sequestration is one of the great challenges of the next few decades in my view, and there are a variety of approaches to take, but the most important approach in terms of how much can be captured is geologic sequestration. Enhanced oil recovery is significant, and it is good for the first few CTL plants. It is important that they probably do something like that, but if we want to go beyond that, we are going to have to do something much more significant. But right now the federal budget

on carbon capture and sequestration is about $80 million a year, and that is just way too low for the challenge that is ahead.

And the critical steps here are to have very large scale demonstrations, and what is important if you have a large scale demonstration is that you don't just focus on the engineering. There is a tremendous amount of basic science, geological sciences, geochemistry, geophysics, that has to accompany any of these large scale demonstrations. Otherwise we really won't understand what we are doing.

And we have good scientists who are working on this, and this is a real big challenge, not just for coal-to-liquids, for everything.

Mr. MATHESON. For everything. Yeah.

Dr. ROMM. If I could just add, the Science Committee has to, I would, if it wants to support carbon capture and storage, should develop an accepted scientific process for identifying and certifying geologic repositories. I mean, I would point out we have spent how long trying to certify one repository for nuclear waste. We are talking about dozens of repositories for carbon dioxide, and we don't have any institutionalized process for how you identify and certify that some repository is going to be safe and permanent.

Mr. MATHESON. Dr. Freerks.

Dr. FREERKS. I do believe that the geo sequestration partnership is doing exactly that. They are looking at sites throughout the U.S. I believe there are seven sites that have been chosen. They are going to sequester millions of tons of CO_2 and prove the capture nature of that geo sequestration and verify all the issues that go along with that, including any leakage and migration.

And there are multiple places where this has already been demonstrated. In Norway there are two major sites that have already been using saline aquifers, and there is Devonian shale in other areas that can store massive amounts of CO_2 by the terms in which we are making CO_2 right now. We can store CO_2 for several hundred years, if not, I think 600 years has been proposed by Dr. Scott Clara of the NETL in their study of geo sequestration.

So there is a lot of data supporting the sequestration of CO_2 for the long-term and making it a viable technology for all of the ways that we produce energy through combustion and CO_2, and then now it really comes down to how do we capture that CO_2 and put it into the ground. Well, coal-to-liquids offers the best opportunity for doing that because we have to capture the CO_2 as part of the process. So there is no inherent additional costs for scrubbing the CO_2 out of our concentrated streams.

Where there would be from coal-fired power plants or from oil refineries or even from fermentation into ethanol.

Mr. MATHESON. Well, Mr. Chairman, I see my time has expired, but I do want to thank the panel, and I would suggest as a Science Committee issue, in terms of figuring out what we can do to encourage understanding of carbon capture sequestration, if any of the witnesses want to provide additional testimony that gives direction for us or any ideas, I think that is an issue that this committee ought to take a look at.

And with that I yield back.

Chairman LAMPSON. Thank you very much. We have passed the Udall legislation that has to do with carbon sequestration, and obviously there is more yet that we have to do.

I have been looking for a way to get Mr. Hall indebted to me. I think I may have just found it. I am going to yield time to Mr. Hall for a question.

Mr. HALL. Mr. Chairman, I will ask a question of you. Are you going to give us some time to send letters——

Chairman LAMPSON. You bet.

Mr. HALL.—and inquiries to these gentlemen?

Chairman LAMPSON. You bet we are.

Mr. HALL. As you may remember, I offered an amendment to the biofuels bill establishing an R&D program, looking into a practice. It was unfortunately voted down during markup, but if you will remember, I had a little better luck on offering a motion to instruct conferees, asking the managers on the part of the House that the conference on H.R. 2272 to be instructed, if you remember that. Insist on language prioritizing the early career grants to science and engineering researchers for the expansion of domestic energy production and use through coal-to-liquids. And this passed by a vote of 258 to 167, and most of you guys over there voted for it.

I am going to write to each of these men and ask them if they favor providing grants to our young scientists and engineers to focus on R&D and these questions and whether or not that is an appropriate or inappropriate expenditure by the Federal Government and recommendation by this group.

And I thank you for your answers, and I thank you, Mr. Chairman. I do owe you.

Chairman LAMPSON. Thank you, Mr. Hall. I think this has been a very informative hearing, and we have, maybe it has raised more questions for some of us than we had when we first came in, and obviously we do want the record to remain open for additional statements from Members and for answers to any follow-up questions that the Committee may ask of the witnesses. I know that I have got some that I will, indeed, be forwarding out to you.

So as we bring this hearing to a close I want to thank the witnesses for testifying before the Committee today. You are excused, and this committee is now adjourned.

[Whereupon, at 12:00 p.m., the Subcommittee was adjourned.]

Appendix:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Richard D. Boardman, Senior Consulting Research and Development Lead, Idaho National Laboratory

Questions submitted by Representative Jerry McNerney

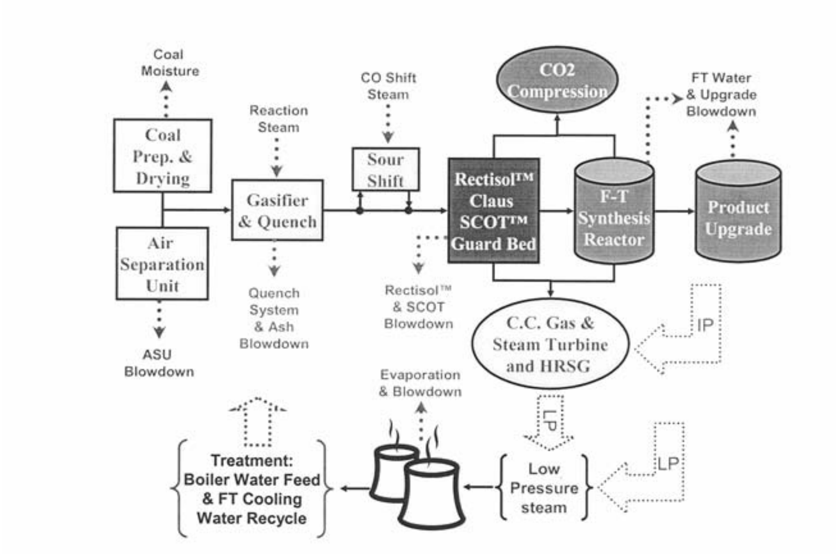
Q1. Expanded use of coal-to-liquids technology could increase the high burden on available water supplies, particularly in the West. You discussed possible technical solutions that would dramatically reduce the amount of water used in the F–T process.

Q1a. Please explain the status of these techniques, how difficult they would be to implement on a large scale, and how costly their implementation might be.

A1a. In my testimony, I stated that the amount of water required for a coal-to-liquids plant could be as high as 8–10 barrels per barrel of diesel fuel produced for an INL case study. This would be the case when no effort is made to treat and recycle the water that is discharged at several locations throughout the plant. The figure below gives a conceptual view of the water input and effluent streams for a notional coal-to-liquid plant. The gasifier is feed coal and steam, at a ratio of about one pound of steam per pound of dried coal (at 10 percent moisture). This translates to roughly 2.5 barrels of water per barrel of F–T product. More water (about one barrel per barrel of liquid product) is injected into the hot syngas to quench the hot syngas in order to remove particulate and soluble pollutants. Additional water is required to produce hydrogen in the CO shift reactor. The typical amount required for the shift reaction is approximately 0.5 barrel of water per barrel of product. Next, a large amount of cooling water must be used to cool the gasifier vessel and the F–T reactors and product upgrade refinery, which ultimately results in low-pressure steam which when vented to the atmosphere can be as much as an additional 4–6 barrels of cooling water per barrel of product. In sum, the water input is about 8 to 10 barrels (or 2.5 + 1 + 0.5 + 4–6 barrels of water).

In order to reduce the water consumption, the moisture that is recovered from the coal drying process can be used to make up the steam that is co-injected with the coal. This amounts to a net gain of one-quarter (1/4) to one (1) barrels of water per barrel of product that can be offset for an eastern coal or western lignite, respectively. Next, water from the air separation unit (ASU) can be obtained, in the amount of about 0.25 barrels of water per barrel of product, depending on the relative humidity which obviously would be less for plant in the Western Mountain States. Quench system water and Rectisol™ blowdown can be treated and used in the plant, netting approximately one (1) barrel more of water per barrel of product. The F–T process also produces about one (1) barrel of water per barrel of F–T product. This by-product water can be treated to remove water-soluble light organics for use throughout the plant. Finally, the cooling tower condensate can be treated and recycled, thus reducing cooling water make up by 67 percent. This would reduce water use by an additional 2.5–4 barrels of water per barrel of F–T fuels product. All of the above process steps should be considered standard practice, and together amount to about 10–15 percent increase in total capital cost and 10 percent in operating costs of the plant. Collectively, these practices would lower the water demand to around 3–5 barrels of water per barrel of product.

Finally, I referred to implementing commercially available, but expensive air-cooler heat exchangers to replace the steam cooling tower. An expensive closed-loop organic refrigerant cycle could also be deployed to cool the low-grade, unusable steam. This option would however be expensive, but could be offset by revenue from surplus power that can be produced by expanding the refrigerant. Both of these options would increase the capital costs by approximately five percent, but would reduce the water demand to 1.5–3 barrels of water per barrel of product.



Q1b. What are the realistic prospects for substantially reducing the amount of water used in coal-to-liquid production?

A1b. As can be seen by my analysis, proper consideration for using the water discharges from coal drying, the quench system, F–T by-product water, and cooling tower operations can significantly cut the water demand, at a cost of around 10–15 percent of the total capital cost of the plant, and an operating cost increase of only 10 percent. For an additional capital cost increase of around five percent, the theoretical water consumption can be reduced to as little as one (1) to two (2) barrels of water per barrel of product. Currently, some projects are claiming they have reduced the water demand to as low as one-half (1/2) barrels of water per barrel of product for a plant using high moisture lignite or sub-bituminous coal, and by implementing all practical water reclamation technology.

Based on my study of refinery plants and coal-fired power plants that already use air-cooler heat exchangers in arid climates, my opinion remains consistent with my testimony; that is, the practical limit of water demand—accounting for 1) potable water use, 2) yard water uses such as dust control, 3) normal steam cleaning of equipment, 4) steam leaks, 5) water discharges limits to existing streams or deep-well injection, 6) practical limits to air-cooler heat exchangers, and 6) cost-risk constraints associated with closed-loop refrigeration—is around three (3) barrels of water to barrel of product.

Q1c. Is it possible to reduce the amount of water required to a low enough level, relative to the price of gasoline, that it is economically viable to produce coal-based fuels on a larger scale?

A1c. Only a subjective opinion can be given to this question, based on semi-technical bias. When the cost of petroleum crude remains above $75–80 per barrel, then my economical assessment indicates that F–T fuels will be competitive with corresponding gasoline costs of around $2.75 per gallon, and diesel fuel cost upwards of $3.10 per gallon, as at the end of the summer season, 2007. This assessment includes both capital and operating costs required to treat and recycle recovered and produced water in the plant to achieve a water consumption rate of 3–5 barrels per barrel of fuel product.

With respect to water demands in the Western U.S., in my testimony, I recommended that water currently being co-produced with conventional crude oil or coal-bed methane production be used to support co-located coal-to-liquids projects. There is sufficient water to supply several large plants for the life span of these plants. It may be necessary to impound, or store this water at some additional cost; however, these costs are not substantial, and would not raise the operating cost

more than approximately five percent. With this nominal increase, F–T diesel fuel would still be competitive with current market prices.

Although the West is water-constrained, the amount of water required for a large complex of coal-to-liquid plants producing upwards of 300,000 barrels of F–T fuels per day, at 3:1 barrels of water per barrel of F–T fuels, would require less than one percent of the upper Colorado River, Columbia River, upper Platt River, and upper Missouri River stream flows.

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